

SMES-ETM
FINAL ENVIRONMENTAL ISSUES
SUMMARY REPORT

(DELIVERABLE 4.5)

DISTRIBUTION STATEMENT A

Approved for public release
Distribution Unlimited

28 NOVEMBER 1989

DMSS/BERGER

PLEASE RETURN TO:

**BMD TECHNICAL INFORMATION CENTER
BALLISTIC MISSILE DEFENSE ORGANIZATION
7100 DEFENSE PENTAGON
WASHINGTON D.C. 20301-7100**

DMIC QUALITY INSPECTED 4

19980309 127

64469

TABLE OF CONTENTS

	<u>Page</u>
Preface	i
1.0 Introduction	1
2.0 Report Structure	1
3.0 Potentially Significant Issues	2
3.1 Methodology for Determining Significance	2
3.2 Environmental Issues	2
3.2.1 Non-Site Specific Issues	2
Technology	2
General Construction	4
3.2.2 Site Specific Issues	5
White Sands Missile Range Site, New Mexico	5
Badger Army Ammunition Plant Site, Wisconsin	5
BPA Hanford Reservation Site, Washington	6
Orogrande Site, New Mexico	7
TU Electric Monahans Site, Texas	7
APPENDIX A - EVALUATION OF SIGNIFICANCE	A-1
APPENDIX B - WHITE PAPER ON ELECTROMAGNETIC EFFECTS	B-26

NOTICE

WASHINGTON DC 20315-1100
1100 OFFICE BUILDING
BATTISCOMBE OFFICE BUILDING
AND TECHNICAL INFORMATION CENTER
NOTICE

Accession Number: 4469

Publication Date: Nov 28, 1989

Title: SMES-ETM, Final Environmental Issues, Summary Report Report Number: Deliverable 4.5

Comments on Document: Deliverable 4.5

Descriptors, Keywords: SMES ETM Environmental Issue Electromagnetic Effect White Sands Missile Range Site

Pages: 00055

Cataloged Date: Apr 22, 1993

Document Type: HC

Number of Copies In Library: 000001

Record ID: 26733

Preface

The Final Environmental Issues Summary Report (Deliverable 4.5) is the fifth deliverable report of thirteen reports and briefings to be prepared under Task Four, Environmental Technical Support for SDIO/ENEC; Superconducting Magnetic Energy Storage (SMES) System EIAP/Siting Support. This Summary Report is prepared in accordance with the SMES-ETM Environmental Impact Assessment Process (EIAP) Implementation Plan (Deliverable 4.2). The EIAP Implementation Plan provides the overall framework within which the environmental impact assessment process for the SMES-ETM Program occurs. The EIAP Implementation Plan is designed to be consistent with the requirements of the National Environmental Policy Act (NEPA). The Environmental Issues Summary Report is a major component of the SMES-ETM environmental impact assessment process. The Summary Report is the identification of potentially significant environmental issues that DNA and SDIO must consider in determining the appropriate level of environmental documentation for the SMES-ETM Program.

The schedule on the following page illustrates the series of reports and briefings required under Task 4, submittal dates of completed tasks, and scheduled submittal dates from Notice to Proceed (NTP) for remaining tasks. The Environmental Issues Summary Report is presented below in relation to the other SMES-ETM deliverables.

**SCHEDULE FOR TASK FOUR DELIVERABLES
NOTICE TO PROCEED 14 AUGUST 1989**

<u>DELIVERABLE</u>	<u>TITLE</u>	<u>STATUS</u>
4.1	BRIEFING: TASK SUMMARY	COMPLETED 30 AUGUST 89
4.2	REPORT: DRAFT EIAP IMPLEMENTATION PLAN	COMPLETED 28 SEPTEMBER 89
	REPORT: FINAL EIAP IMPLEMENTATION PLAN	COMPLETED 28 NOVEMBER 89
4.3	REPORT: DRAFT DOPAA	COMPLETED 11 OCTOBER 89
4.4	REPORT: FINAL DOPAA	IN PROGRESS COMPLETION: 28 November 89
4.5	REPORT: FINAL ENVIRONMENTAL ISSUES SUMMARY	COMPLETED 28 NOVEMBER 89
	REPORT: TECHNICAL WHITE PAPER; Electromagnetic Effects	COMPLETED 28 NOVEMBER 89
4.6	REPORT: TECHNICAL ANALYSIS	IN PROGRESS COMPLETED 28 NOVEMBER 89
4.7	BRIEFING: TECHNICAL ANALYSIS	IN PROGRESS COMPLETION: 1 DECEMBER 89
4.8	REPORT: PRELIMINARY DRAFT ENVIRONMENTAL ASSESSMENT	165 DAYS FROM NTP
4.9	RESPOND TO COMMENTS PRELIMINARY DRAFT ENVIRONMENTAL ASSESSMENT	190 DAYS FROM NTP
4.10	REPORT: DRAFT ENVIRONMENTAL ASSESSMENT	205 DAYS FROM NTP
4.11	REPORT: DRAFT FINDING OF NO SIGNIFICANT IMPACT	205 DAYS FROM NTP
4.12	REPORT: DRAFT ENVIRONMENTAL ASSESSMENT MEETING	210 DAYS FROM NTP
4.13	REPORT: FINAL ENVIRONMENTAL ASSESSMENT	240 DAYS FROM NTP

1.0 Introduction

The purpose of the Final Environmental Issues Summary is to provide DNA and SDIO with an overall picture of the potentially significant environmental issues associated with the SMES-ETM Program.

These issues are related to SMES-ETM technology, general construction practices that are generic to all sites, and site specific constraints. The potentially significant issues were determined by screening all environmental issues found in Appendix A against the NEPA criteria for significance. Appendix A, Evaluation of Significance, is based on a review of the GFI, telephone conversations, and field investigations. Field investigations were conducted for all sites except for White Sands Missile Range (WSMR), access to which was restricted at the time. However, GFI for WSMR was reviewed and field contacts at the Orogrande site often covered resources common to both sites.

During the preparation of the Preliminary Environmental Issues Summary, a parallel effort was undertaken on potential technology specific environmental issues. This effort resulted in a separate white paper on electromagnetic effects that is summarized in this document and found in full in Appendix B. Therefore, this document presents the integration of both technology and site specific issues for consideration by DNA and SDIO.

2.0 Report Structure

This Final Environmental Issues Summary is divided into three sections: the main text which identifies potentially significant issues; Appendix A, Evaluation of Significance; and Appendix B, Technical White Paper on Electromagnetic Effects.

The main text addresses only those issues that are deemed Potentially Significant based upon the ten elements for determining significance established in NEPA and restated in the EIAP Implementation Plan.

Appendix A presents a brief description of salient issues obtained to date for each resource area by site. This information is also presented in a matrix format that evaluates each discipline as Potentially Significant (PS) or No Significant Issues Identified to Date (NS).

The effects of Electromagnetic Fields upon living organisms is an issue that may be the governing factor in the decision to develop an EA or an EIS. As such, Appendix B is a White Paper which discussed the technical aspects known to date of these fields upon living organisms. Included in this report is a literature review and a discussion on various approaches to scientific investigation. A brief summary of information contained in Appendix B is included in the main text in a section entitled Technology (3.2.1 Non-Site Specific Issues).

3.0 Potentially Significant Issues

3.1 Methodology for Determining Significance

Information gleaned from GFI, telephone conversations, and initial field visits was analyzed by each resource specialist in order to determine the environmental issues associated with each respective resource on a site specific basis. Generic non-site specific environmental issues were also reviewed.

An evaluation of potential environmental issues associated with SMES-ETM technology was conducted. This included reviewing SMES-ETM technical documents, reviewing publications on SMES-ETM technology, and reviewing environmental documentation for the Superconducting Super Collider. In addition, conversations were held with representatives of Fermi-lab, the national particle accelerator in Illinois, and SSC representatives at the Department of Energy on shielding of steady magnetic fields.

The literature review that was conducted on electromagnetic effects generally, and time-varying and steady magnetic fields in particular, was comprehensive as is evidenced by the bibliography found in the SMES-ETM Electromagnetic Effects Working Paper located in Appendix B of this document.

Each of these issues were then analyzed against the ten NEPA criteria of significance found in Appendix A, Section 1.0. Significance is a measure of the importance of an impact. Impacts identified as significant must be taken into consideration by the decisionmaker; but not all significant impacts must be avoided. Significance is a function of the interaction between level of impact and the context in which the impact occurs. Context represents the various qualitative conditions present in the existing environment which operate to magnify or diminish the importance of the impact. Those environmental issues that potentially meet any of the criteria are determined to be potentially significant. Only those issues deemed potentially significant are discussed in this section.

3.2 Environmental Issues

3.2.1 Non-Site Specific Issues

Technology

The major technological concern is related to the electromagnetic fields produced by a SMES-ETM and its connection to the electrical grid system. Electromagnetic fields are divided into two components: electrical fields and the magnetic fields. Alternating electrical currents (AC) produce oscillating electrical and magnetic fields which in turn produce electromagnetic waves. The types of fields that are of concern are the strong steady magnetic fields produced by the SMES-ETM coil and the much weaker oscillating electromagnetic fields produced by the transmission lines connecting the SMES-ETM to the electrical grid, the converter

which converts AC to DC to feed the SMES-ETM and DC to AC to draw energy from the SMES-ETM, and by the "ripple" in the DC current in the SMES-ETM coil.

The two areas of concern are dangers to public health and impacts on wildlife, and particularly birds.

The effects of steady magnetic fields on human health are relatively well known, and it is possible to protect humans from them. The general public will be excluded from areas of risk by the facility's perimeter fence, and it is assumed that facility employees will be protected by the application of appropriate safety rules and practices. The only area of significant concern is the 10-gauss restriction zone. According to information provided, the perimeter fence line is to be placed at the 10 gauss contour. Certain types of artificial cardiac pacemakers are effected at fields as low as 8 gauss and could malfunction in fields of 13/14 gauss. The FDA has published guidelines to exclude people with pacemakers from fields higher than 5 gauss around nuclear magnetic resonance imaging equipment¹, and it is reported that the 5 gauss line is painted on floors of hospitals in Japan to exclude people with pacemakers². The Lawrence Livermore National Laboratory (LLNL) set a 10 gauss limit for their magnetic confinement experiment and the Japanese Railways are also proposing a 10-gauss limit for the passenger compartment of their mag-lev trains. However, the LLNL limit was set to avoid the relocation of a major road³, and there is controversy over the Japanese Railways proposal.

In addition to potential effects on humans, steady magnetic fields may affect avian navigation. It is suspected that birds use the earth's magnetic field to navigate. Whereas the magnetic navigation mechanism of certain ocean fish has been established, little is known about the navigation mechanism of birds. Most authorities appear to agree that magnetic fields may impact the navigation mechanisms of migratory birds. However, the literature suggests that effects may not be more than transient. The effects of magnetic fields on avian navigation may range from temporary to long-lost disassociation. Experiments with homing pigeons subjected to 10 Tesla for one minute showed that the birds were disoriented six weeks. While the SMES-ETM would not produce magnetic field of this magnitude, lower force fields may disorient birds migrating over the site. Several of the sites are on known migratory pathways. It is inconclusive as to what impacts a SMES-ETM would have on migratory birds.

There has been increasing concern over the health impacts of oscillating electromagnetic fields from power lines and radio/radar stations. A number of epidemiological and experimental studies have linked various forms of cancer and other adverse human health effects with these electromagnetic fields. Recent

¹ Food and Drug Administration, Guidance for Content and Review of Magnetic Resonance Diagnostic Devices, 501(K) (Application), August 2, 1988, Rockville, MD 20857

² Railway Gazette International, Keep off the Gauss, p. 704, October 1989

³ Miller, G., Exposure Guidelines for Magnetic Fields, Am. Ind Hyg. Assoc. J. 48(12):962 (1987)

experimental work has demonstrated possible biological processes causing these effects. A recent series of articles in the New Yorker Magazine has highlighted these concerns among the public⁴. A fair summary of these studies is that they indicate a strong ground for concern but do not establish the linkage.

In addition to a steady magnetic field, the SMES-ETM coil produces an oscillating magnetic field due to the conversion process of the DC from AC. However, the conversion process is highly sophisticated and has to reduce this ripple to a low level for the SMES-ETM to function efficiently. It is doubtful if any members of the public or facility staff will be exposed to levels of oscillating magnetic fields approaching those at which any effects on humans have been observed. However, Bechtel has indicated that the precise levels of the ripple causing oscillating fields will only be known once the SMES-ETM is operational⁵ and therefore this finding cannot be substantiated.

The transmission lines connecting the SMES-ETM to the electrical grid and the converter also produce oscillating electromagnetic fields. It is assumed that the transmission lines can be placed away from residences and other areas occupied by humans and thus pose no risk to public health.

General Construction

The only potentially significant environmental issue that has been identified and that is generic to all sites for which construction activities occur is cultural resources. All sites have the potential for significant archeological or historic finds. However, this cannot be determined until complete site surveys or construction activities occur.

For cultural resources, investigations of the sites are conducted through Section 106 process pursuant to the National Historic Preservation Act. The NEPA and Section 106 processes can occur simultaneously when the use of federal funds are involved in the project. Section 106 requires certain investigative steps be taken. Archeological or historic architectural finds at a particular site does not necessarily govern the decision to develop an Environmental Assessment (EA) or to proceed to an Environmental Impact Statement (EIS). The 106 process in itself determines the extent to which investigation is required.

To date step 1A, literature search and reconnaissance (windshield) inspection, have been conducted at each of the alternative sites and as noted in Appendix A of this report. Cultural resource potential at each of the sites is identified as potentially significant. This identification will not impact a decision on the NEPA process, but may affect construction costs and schedules should extensive and significant properties occur at the selected site. (Significant

⁴ Brodeur P., Annals of Radiation: the Hazards of Electromagnetic Fields, New Yorker Magazine, June 12, 19 and 26, 1989

⁵ Letter from Bechtel National Inc. to Louis Berger & Associates, Inc. dated October 13, 1989

properties being those that meet the criteria for inclusion in the National Register of Historic Places. The literature search and reconnaissance inspection, Phase IA, fulfills NEPA requirements so that subsequent activities fall within the 106 process.)

3.2.2 Site Specific Issues

The following issues are identified as potentially significant based upon NEPA criteria presented in Appendix A.

White Sands Missile Range Site, New Mexico

Biological Resources

The potential for magnetic effects on listed or candidate bird, bat species, and waterfowl clearly exists. Five federally listed threatened and/or endangered species are known to inhabit the area, but not specifically the site. The listed species are: The American peregrine falcon, aplomado falcon, bald eagle, whooping crane, and the interior least tern.

Two federally listed threatened and/or endangered plant species are known to inhabit the area and may be located on the site, Sneed's pinchusion cactus and Lloyd's hedgehog cactus. This determination cannot be made until spring when flowering occurs.

Cultural Resources

It is likely that the New Mexico State Historic Preservation Officer (SHPO) will require Phase I studies at the site. Phase II and III levels of investigation may also be required.

A memorandum of agreement between the New Mexico State Historic Society and DoD states that "a 100% survey will be conducted to identify and evaluate... resources for activities on WSMR." The potential for discovery of cultural resources appears to be quite high. In fact, sixty six (66) archaeological properties were previously recorded during a recent survey in the vicinity of the SMES-ETM site.

Badger Army Ammunition Plant Site, Wisconsin

Biological Resources

The potential for magnetic affects on avian species exists. Approximately 20 bald eagles which are classified as threatened and endangered species have been observed nesting and feeding within 2-3 miles of the proposed site.

The site is located near Baraboo bluffs which is one of the largest forested areas left in Wisconsin and is a major habitat for songbirds. In addition, large numbers of Sandhill Cranes nest near Baraboo.

Cultural Resources

Prior work indicates that the cultural resource potential of the proposed site is low. However, this conclusion appears to be based on a study that was recognized as "very preliminary" and may now be out of date. During field investigations, prehistoric and historic recorded sites were identified. In addition, one unrecorded brick foundation was observed at the proposed SMES-ETM location.

BPA Hanford Reservation Site, Washington

Biological Resources

Threatened and Endangered Species

The potential for magnetic affects on avian species exists for several protected birds and could possibly result in direct effects on the long-billed curlew.

The sand hill crane, which is on the threatened/endangered species list, has been observed flying over the area, but evidence of nesting in the vicinity is inconclusive. The bald eagle could also be affected. Three federal candidate species that use the site could be affected: swainson hawks, ferruginous hawks and the long billed curlew.

Several state species of concern use the site: northern grasshopper mouse, night snake and striped whipsnake. Although they are not listed as federally threatened and endangered species, they are listed as candidate species by the State of Washington.

The site is located under a major avian flyway. Because of the proximity of the site to the Columbia River, a large number of mallards winter in the area. It is believed that one-tenth of the mallard population winters within 50 miles of the site.

The threatened and endangered Columbia milkvetch plant species is located on the northern part of the reservation, but not specifically the site.

Cultural Resources

Gable Mountain, which is adjacent to the proposed site, has been nominated to the National Register of Historic Places for its Native American religious significance. Although the concerned tribes appear to view the proposed development favorably, the status of the cultural property and its significance to the local tribes remains a potential management issue.

The nearest cultural resource sites are located on the west end of Gable Mountain, 4 miles from this site. A literature review of the site was conducted and found no evidence of cultural resources. However, an on-site investigation was not conducted.

Orogrande Site, New Mexico

Biological Resources

The potential effects upon avian species exists. Five federally listed threatened and/or endangered species are known to inhabit the area, but not specifically the site. The listed species are: the American peregrine falcon, aplomado falcon, bald eagle, whooping crane and the interior least tern.

Sneed's Pincushion Cactus, and Lloyd's Hedgehog Cactus, threatened and/or endangered plant species are known to be present in the area and may be located on the site. This determination cannot be made until spring when flowering occurs.

The Jarilla mountains which are located adjacent to the site and are disjunct from other mountains in the vicinity may contain distinct plant and animal species. Lloyd's Hedgehog Cactus is found on the mountain range.

Geology

There is a concern over water availability to the SMES-ETM. Indications are that the proposed utility may have over appropriated its water rights.

Cultural Resources

The general area appears to have been investigated but the parameters of a 1985 study are vague. The site contains archaeological remains believed to reflect a land use pattern involving seasonal exploitation of basin floor resources. Recent excavations of small basic floor sites suggest that many of the medium to large formative period sites will contain small huts or pithouses. During field investigations, archaeological remains were observed at the Orogrande site.

TU Electric Monahans Site, Texas

Biological Resources

Seven federally listed threatened and/or endangered species and four candidate species have ranges that may include the general area: The American peregrine falcon, arctic peregrine falcon, bald eagle, interior least tern, piping plover, black-capped vireo, and possibly the whooping crane. Candidate species are: western yellow-billed cuckoo, southern spotted owl, Arizona prairie dog, and one species of cyprus.

The Texas horned lizard is the only state or federally threatened species on site that could be effected by operation of SMES-ETM.

The site is located under an avian flyway. Since water is not available in the immediate area birds may not inhabit the area long enough to experience any

potential adverse effects. However, disorienting effects in flight are unknown at this time.

Cultural Resources

Prior studies indicate that the cultural resource potential is "moderate to high." The site is used for petroleum production and has a high to moderate potential for the discovery of significant archaeological and cultural resources.

APPENDIX A - EVALUATION OF SIGNIFICANCE

APPENDIX A - EVALUATION OF SIGNIFICANCE

Appendix A evaluates the degree of significance attributable to each resource area and subdiscipline based upon review of GFI, telephone conversations, and field visits. Items that are considered Potentially Significant are presented in Section 3.2.2.

The degree of significance used to evaluate each resource area is taken from NEPA criteria (40CFR 1502.16) and listed below:

- 1) Impacts that may be both beneficial and adverse. A significant effect may exist even if it is determined that on balance the effect will be beneficial;
- 2) The degree to which the proposed action affects public health and safety;
- 3) Unique characteristics of the geographic area such as proximity to historic or cultural resources, parklands, prime farmlands, wetlands, wild and scenic rivers, or ecologically critical areas;
- 4) The degree to which the effects on the quality of the human environment are likely to be highly controversial;
- 5) The degree to which the possible effects on the human environment are highly uncertain or involve unique or unknown risks;
- 6) The degree to which the action may establish a precedent for future actions with significant effects or represents a decision in principle about a future consideration;
- 7) Whether the action is related to other actions with individually insignificant but cumulatively significant impacts. Significance exists if it is reasonable to anticipate a cumulatively significant impact on the environment. Significance cannot be avoided by terming an action temporary or by breaking it down into small component parts;
- 8) The degree to which the action may adversely affect districts, sites, highways, structures, or objects listed in or eligible for listing in the national register of historic places or may cause loss of destruction of significant scientific, cultural, or historical resources;
- 9) The degree to which the action may adversely affect an endangered or threatened species or its habitat that has been determined to be critical under the endangered species act of 1973; and
- 10) Whether the action threatens a violation of federal, state or local law or requirements imposed for the protection of the environment.

The five alternative sites examined for siting of the SMES-ETM are presented below. Items gleaned from GFI and field visits are presented in narrative form (below) which are then evaluated against the NEPA criteria for significance. NEPA criteria has been truncated for use in a matrix format.

White Sands Missile Range Site, New Mexico

Biological Resources

■ Vegetation

To date no issues have been identified for this resource area.

■ Wildlife

Populations of wildlife in the immediate vicinity of the site could expect effects ranging from premature mortality to temporary construction noise displacement.

The potential for magnetic effects on listed or candidate bird, bat species, and waterfowl clearly exists. This would include two candidate (threatened and/or endangered) bird species that could experience adverse effects.

■ Aquatic Resources

To date no issues have been identified for this resource area.

■ Wetlands

To date no issues have been identified for this resource area.

■ Threatened and Endangered Species

Seven federally listed threatened and/or endangered species are known to inhabit the area, but not specifically the site. The listed species are: The American peregrine falcon, aplomado falcon, bald eagle, whooping crane, interior least tern, Sneed's pincushion cactus and Lloyd's hedgehog cactus.

Geology/Water Resources

To date no issues have been identified for this resource area.

■ Seismic

WSMR is classified as a zone 2 seismic risk (On a scale of 1 to 4, 4 is considered the greatest seismic risk.).

■ Water Hydrology

Only a few low-capacity wells operate in the immediate vicinity of the site. Two springs are near the site: Cottonwood (1.4 Km South) and Ropes (6.4 Km S.E.).

Air/Noise Resources

■ Air

To date no issues have been identified for this resource area.

■ Noise

Weapons firings and supersonic air operations produce peak noises in excess of 146 decibels (db) at WSMR. At times these noise sources can be heard in areas off the range, however, no specific data at the candidate site is available.

Socioeconomic Resources

■ Employment

To date no issues have been identified for this resource area.

■ Population and Housing

To date no issues have been identified for this resource area.

■ Public Services and Facilities

To date no issues have been identified for this resource area.

■ Fiscal Resources

To date no issues have been identified for this resource area.

■ Quality of Life

To date no issues have been identified for this resource area.

■ Land Use

To date no issues have been identified for this resource area.

Utilities/Energy Resources

■ Electric Utilities/Telephone/Pipelines

To date no issues have been identified for this resource area.

■ Magnetic Fields

See Appendix B, White Paper on Electromagnetic Fields.

■ Energy Resources

To date no issues have been identified for this resource area.

- Industrial and Construction Resources

To date no issues have been identified for this resource area.

Transportation

- Road System

To date no issues have been identified for this resource area.

- Railroads

To date no issues have been identified for this resource area.

- Airports

To date no issues have been identified for this resource area.

- Public Transportation

To date no issues have been identified for this resource area.

Hazardous Wastes

- Non-Radioactive Wastes

To date no issues have been identified for this resource area.

- Radioactive Wastes

To date no issues have been identified for this resource area.

Cultural Resources

It is likely that the New Mexico State Historic Preservation Officer (SHPO) will require Phase I studies at the site. Phase II and III levels of investigation may also be required.

A memorandum of agreement between the New Mexico State Historic Society and DoD states that "a 100% survey will be conducted to identify and evaluate... resources for activities on WSMR." The potential for discovery of cultural resources appears to be quite high. In fact, sixty six (66) archaeological properties were previously recorded during a recent survey in the vicinity of the site.

Other Issues

The WSMR SMES-ETM Site poses a potential conflict with other existing and proposed WSMR programs. A possibility of interference with NASA's Telemetry Data Relay Satellite System with radio frequency and electromagnetic emissions exists. Use of this site potentially conflicts with two ongoing missile programs and lies within the Yonder Aerial Gunnery Training Range.

Potential interference with air space activities conducted at WSMR and Fort Bliss might result in potential for opposition.

WHITE SANDS MISSILE RANGE SITE
SIGNIFICANCE MATRIX BY MAJOR RESOURCE AREA

RESOURCE AREA

<u>NEPA Criteria</u>	<u>Biological Resources</u>	<u>Geology Water</u>	<u>Air/Noise</u>	<u>Socioeconomic</u>	<u>Utilities/ Energy</u>	<u>Transportation</u>	<u>Hazardous Waste</u>	<u>Cultural Resources</u>	<u>Other Issues</u>
1. Beneficial or Adverse Impact	PS	NS	NS	NS	NS	NS	NS	PS	NS
2. Affects Public Health or Safety	NS	NS	NS	NS	NS	NS	NS	NS	NS
3. Unique Geographic Characteristics	NS	NS	NS	NS	NS	NS	NS	NS	NS
4. Controversial Impact on Human Environment	NS	NS	NS	NS	NS	NS	NS	NS	NS
5. Uncertain or Unique Risks	PS	NS	NS	NS	NS	NS	NS	NS	NS
6. Establish a Precedence	PS	NS	NS	NS	NS	NS	NS	NS	NS
7. Cumulative Significant Impact	NS	NS	NS	NS	NS	NS	NS	NS	NS
8. Adversely Affect Resources	NS	NS	NS	NS	NS	NS	NS	PS	NS
9. Threatened or Endangered Species	PS	NS	NS	NS	NS	NS	NS	NS	NS
10. Violation of Federal, State and Local Laws	PS	NS	NS	NS	NS	NS	NS	PS	NS

LEGEND:

N.S. = No Significant Issues Identified to Date.

P.S. = Potentially Significant.

Badger Army Ammunition Plant Site, Wisconsin

Biological Resources

■ Vegetation

To date no issues have been identified for this resource area.

■ Wildlife

Populations of wildlife in the immediate vicinity of the site could expect effects ranging from premature mortality to temporary construction noise displacement.

Approximately 20 bald eagles which are classified as threatened and endangered species have been observed nesting within the general vicinity of the proposed site.

The opossum (Didelphis Virginiana) has extended its range into this area over the last few years. However, the opossum is not a threatened or endangered species.

An EA previously completed; states that the BAAP installation lies within the "Mississippi Flyway", a route for migratory waterfowl. The short-term effects of magnetic fields on migratory birds has not been adequately addressed.

The site is located near the Baraboo bluffs which is one of the largest forested areas left in Wisconsin and is a major habitat for songbirds.

■ Aquatic Resources

To date no issues have been identified for this resource area.

■ Wetlands

A wetlands area has been identified within the site area.

■ Threatened and Endangered Species

See bald eagle discussion above.

Geology/Water Resources

New EPA water quality criteria may soon supercede existing industrial waste sewer and sanitary sewage treatment plant capabilities at BAAP. However, a proposed military construction army project to upgrade/replace the existing plant will comply with treatment criteria.

- **Geologic Resources**

To date no issues have been identified for this resource area.

- **Seismic**

To date no issues have been identified for this resource area.

- **Water/Hydrology**

Groundwater Pollution

Ballistics Pond: Recent tests show that the pond contains contaminants above threshold required by law. However, an additional monitoring well is needed to determine conclusively the direction of groundwater flow and whether any contamination from the pond is affecting the groundwater quality in the area.

Landfill: Recent data indicates that the groundwater in some areas around and under the landfill is contaminated. The possibility that the groundwater North, Northwest, and South of the existing landfill is contaminated should be investigated.

Deterrent Burning Ground: Evacuation of contaminated soils is recommended as an interim remedial action, mainly to prevent further migration of contaminants to other areas of BAAP.

Nitroglycerin Pond: The primary environmental concern is contamination of groundwater by ng, which is both toxic and carcinogenic and it's less-toxic degradation by-product.

Propellant Burning Grounds: Based upon acquired soil and groundwater data, the propellant burning ground has caused environmental pollution.

Rocket Paste Site: The primary chemical parameters of concern for sediment in the rocket-paste area pond and drainage ditch are lead, explosives, and explosive related compounds. Water percolating through the pond and drainage ditch could carry the contaminant and cause significant groundwater contamination.

Settling Ponds and Spoil Disposal Sites: Based upon studies, the creek/pond area, including spoil disposal sites has caused groundwater contamination. The contaminated groundwater plume may have migrated into the area south of the plant boundary.

Air/Noise Resources

- **Air Pollution**

Standby status includes operation of the following: open burning, the decontamination oven, small steam generating units, burning grounds, and contaminants waste processor.

- Burning Grounds

Specific data is not available.

- Open Burning

Operates under a hazardous waste facility (Burning Ground) interim license.

- Noise

Noise levels above acceptable limits exist in certain operating areas. These areas have been properly posted and exposed workers have been provided with appropriate protection.

- Noxious Odors

Noxious odors emanate from various burning grounds and solvent recovery areas. Normally, these odors are contained within the facility or dissipated into the atmosphere inside the plant boundaries.

Socioeconomic Resources

- Employment

To date no issues have been identified for this resource area.

- Population and Housing

To date no issues have been identified for this resource area.

- Public Services and Facilities

To date no issues have been identified for this resource area.

- Fiscal Resources

To date no issues have been identified for this resource area.

- Quality of Life

To date no issues have been identified for this resource area.

- Land Use

To date no issues have been identified for this resource area.

Utilities/Energy Resources

- Electric Utilities/Telephone/Pipelines

To date no issues have been identified for this resource area.

- Magnetic Fields

See Appendix B, White Paper on Electromagnetic Fields or 3.2.1, Non-Site Specific Issues, Technology.

- Energy Resources

To date no issues have been identified for this resource area.

- Industrial and Construction Resources

To date no issues have been identified for this resource area.

Transportation

To date no issues have been identified for this resource area.

- Road System

To date no issues have been identified for this resource area.

- Railroads

To date no issues have been identified for this resource area.

- Airports

To date no issues have been identified for this resource area.

- Public Transportation

To date no issues have been identified for this resource area.

Hazardous Wastes

- Non-Radioactive Wastes

Plant facilities, landfill and a burning pit are located within 1/4 to 3/8 mile of the proposed site. Extensive discharges of contaminants to groundwater during the plants active periods suggests extensive groundwater pollution.

- Radioactive Wastes

To date no issues have been identified for this resource area.

Cultural Resources

Prior work indicates that the cultural resource potential of the proposed site is low. However, this conclusion appears to be based on a study that was recognized as "very preliminary" and may now be out of date. During field investigations, prehistoric and historic recorded sites were identified. In addition, one unrecorded brick foundation was observed at the proposed SMES-ETM location.

Other Issues

To date no issues have been identified for this resource area.

BADGER ARMY AMMUNITION PLANT (BAAP) SITE
SIGNIFICANCE MATRIX BY MAJOR RESOURCE AREA

RESOURCE AREA

<u>NEPA Criteria</u>	<u>Biological Resources</u>	<u>Geology Water</u>	<u>Air/Noise</u>	<u>Socioeconomic</u>	<u>Utilities/ Energy</u>	<u>Transportation</u>	<u>Hazardous Waste</u>	<u>Cultural Resources</u>	<u>Other Issues</u>
1. Beneficial or Adverse Impact	PS	NS	NS	NS	NS	NS	NS	PS	NS
2. Affects Public Health or Safety	NS	NS	NS	NS	NS	NS	NS	NS	NS
3. Unique Geographic Characteristics	NS	NS	NS	NS	NS	NS	NS	NS	NS
4. Controversial Impact on Human Environment	NS	NS	NS	NS	NS	NS	NS	NS	NS
5. Uncertain or Unique Risks	PS	NS	NS	NS	NS	NS	NS	NS	NS
6. Establish a Precedence	PS	NS	NS	NS	NS	NS	NS	NS	NS
7. Cumulative Significant Impact	NS	NS	NS	NS	NS	NS	NS	NS	NS
8. Adversely Affect Resources	NS	NS	NS	NS	NS	NS	NS	PS	NS
9. Threatened or Endangered Species	PS	NS	NS	NS	NS	NS	NS	NS	NS
10. Violation of Federal State, and Local Laws	PS	NS	NS	NS	NS	NS	NS	PS	NS

LEGEND:

N.S. = No Significant Issues Identified to Date.

P.S. = Potentially Significant.

BPA Hanford Reservation Site, Washington

Biological Resources

■ Vegetation

Fauna

The following ecologically sensitive and protected areas are within 10 miles of the site:

- Habitats for state and federal threatened or endangered species
- Freshwater marshes
- Riparian zones
- Breeding and spawning habitats for Chinook Salmon and Steelhead Trout
- A designated unique habitat and fishing area
- The arid lands ecology reserve
- Wildlife

Populations of wildlife in the immediate vicinity of the site could expect effects ranging from premature mortality to temporary construction noise displacement.

This location also has the potential for magnetic effects on concentrations of migrating waterfowl, particularly mallards, other ducks, and geese. The general area provides important habitat for hundreds of thousands of waterfowl.

■ Aquatic Resources

To date no issues have been identified for this resource area.

■ Wetlands

To date no issues have been identified for this resource area.

■ Threatened and Endangered Species

The construction of SMES-ETM at BPA Hanford is expected to result in indirect results on several protected bird and, possibly result in direct effects on the long-billed curlew.

The sand hill crane, which is on the threatened/endangered species list, has been observed flying over the area, but evidence of nesting in the vicinity is inconclusive.

The bald eagle could also be indirectly effected through localized reduction of prey populations, or avoidance of the area during noise-generating construction activities.

The three federal candidate species that use the site could be affected: swainson hawks, ferruginous hawks and the long billed curlew.

Several state species of concern use the site: northern grasshopper mouse, night snake and striped whipsnake. Although they are not listed as federally threatened and endangered species, they are listed as candidate species by the State of Washington.

The site is located under a major avian flyway. Because of the proximity of the site to the Columbia River, a large number of mallards winter in the area. It is believed that one-tenth of the mallard population winters within 50 miles of the site.

The threatened and/or endangered Columbia milkvetch plant species is located on the northern part of the reservation, but not specifically the site.

Geology/Water Resources

■ Water

The source of water for the site or proposed project would be the Columbia River. Although the river has not frozen in recent years, a freeze on the water source could affect plant operations.

■ Groundwater

An underground disposal site for radioactive wastes is located immediately adjacent to the Northwest corner of the site. Low-level waste placed in cartons was buried in trenches, and medium to high level waste was buried in caissons or pipe facilities.

■ Seismic

Seismic activity above magnitude 3.0 on the Richter Scale has occurred in this region. The BPA Hanford site is in Zone 2 of the Uniform Building Code classification which corresponds to moderate seismic risk.

■ Soils

Surface sediments at the site are not considered to be acceptable as a foundation material for the SMES-ETM facility. However past experience in free-standing rock excavations has shown no major stability problems.

Air/Noise Resources

To date no air/noise issues have been identified for this particular resource area.

Socioeconomic Resources

- Employment

To date no issues have been identified for this resource area.

- Population and Housing

To date no issues have been identified for this resource area.

- Public Services and Facilities

To date no issues have been identified for this resource area.

- Fiscal Resources

To date no issues have been identified for this resource area.

- Quality of Life

To date no issues have been identified for this resource area.

- Land Use

To date no issues have been identified for this resource area.

Utilities/Energy Resources

- Electric Utilities/Telephone/Pipelines

BPA owns the 500-KV power line that runs across the northeast corner of the area. The DOE owns the 120-KV powerline that runs east-west along the southern boundary of the area. The possibility of electromagnetic interference exists.

- Magnetic Fields

See Appendix B, White Paper on Electromagnetic Fields or 3.2.1, Non-Site Specific Issues, Technology.

- Energy Resources

To date no issues have been identified for this resource area.

- Industrial and Construction Resources

To date no issues have been identified for this resource area.

Transportation

■ Road System

To date no issues have been identified for this resource area.

■ Railroads

To date no issues have been identified for this resource area.

■ Airports

To date no issues have been identified for this resource area.

■ Public Transportation

To date no issues have been identified for this resource area.

Hazardous Wastes

■ Radioactive and Non-Radioactive Wastes

The EPA proposes to include four (4) sites within the Reservation on its Superfund National Priority List. Two of these are in the vicinity of the SMES-ETM site. Both areas have extensive contamination by radioactive, mixed and hazardous wastes.

Cultural Resources

Gable Mountain, which is adjacent to the proposed site, has been nominated to the National Register of Historic Places for its Native American religious significance. Although the concerned tribes appear to view the proposed development favorably, the status of the cultural property and its significance to the local tribes remains a potential management issue.

The nearest cultural resource sites are located on the west end of Gable Mountain, 4 miles from this site. A literature review of the site was conducted and found no evidence, however, an on-site investigation was not conducted.

Other Issues

To date no issues have been identified for this resource area.

BPA/HANFORD RESERVATION SITE
SIGNIFICANCE MATRIX BY MAJOR RESOURCE AREA

RESOURCE AREA

<u>NEPA Criteria</u>	<u>Biological Resources</u>	<u>Geology Water</u>	<u>Air/Noise</u>	<u>Socioeconomic</u>	<u>Utilities/ Energy</u>	<u>Transportation</u>	<u>Hazardous Waste</u>	<u>Cultural Resources</u>	<u>Other Issues</u>
1. Beneficial or Adverse Impact	PS	NS	NS	NS	NS	NS	NS	PS	NS
2. Affects Public Health or Safety	NS	NS	NS	NS	NS	NS	NS	NS	NS
3. Unique Geographic Characteristics	NS	NS	NS	NS	NS	NS	NS	NS	NS
4. Controversial Impact on Human Environment	NS	NS	NS	NS	NS	NS	NS	NS	NS
5. Uncertain or Unique Risks	PS	NS	NS	NS	NS	NS	NS	NS	NS
6. Establish a Precedence	PS	NS	NS	NS	NS	NS	NS	NS	NS
7. Cumulative Significant Impact	NS	NS	NS	NS	NS	NS	NS	NS	NS
8. Adversely Affect Resources	NS	NS	NS	NS	NS	NS	NS	PS	NS
9. Threatened or Endangered Species	PS	NS	NS	NS	NS	NS	NS	NS	NS
10. Violation of Federal State and Local Laws	PS	NS	NS	NS	NS	NS	NS	PS	NS

LEGEND:

N.S. = No Significant Issues Identified to Date.

P.S. = Potentially Significant.

Orogrande Site, New Mexico

Biological Resources

■ Vegetation

To date no issues have been identified for this resource area.

■ Wildlife

Populations of wildlife in the immediate vicinity of the site could expect effects ranging from premature mortality to temporary construction noise displacement.

■ Aquatic Resources

To date no issues have been identified for this resource area.

■ Wetlands

To date no issues have been identified for this resource area.

■ Threatened and Endangered Species

Seven federally listed threatened and/or endangered species are known to inhabit the area, but not specifically the site. The listed species are: the American peregrine falcon, aplomado falcon, bald eagle, whooping crane, interior least tern, Sneed's pincushion cactus, and Lloyd's hedgehog cactus.

The Jarilla mountains, which are located adjacent to the site and are disjunct from other mountains in the vicinity may contain distinct plant and animal species. Lloyd's Hedgehog Cactus is found on the mountain range.

The site is located under an avian flyway. Since water is not available in the immediate area it is unlikely species will inhabit the area long enough to experience any potential adverse effects.

Potential for magnetic effects on listed or candidate designated bird, bat species, and waterfowl potentially exists. This would include two candidate designated bird species that could experience adverse effects.

Geology/Water Resources

■ Geologic Resources

There is a concern over water availability to the SMES-ETM. Indications are that the proposed utility has over appropriated its water rights.

■ Seismic

The project region is currently listed as a Uniform Building Code seismic risk zone 1 (minor damage)/Zone 2 (moderate damage). The region may be upgraded, possibly to Zone 3 (major damage) owing to fault systems in the area including one located in the White Sands Missile Range area which has apparently not shown movement over the last several hundred years.

■ Water/Hydrology

Wells drilled near the site encountered water at 228.6 meters. As many as 20 supply wells may be required to provide water in the quantities required to support the SMES-ETM.

The groundwater resources in the project area have a high total dissolved solids (TDS) concentration of the order of 10,000 ppm which makes them unsuitable for human consumption without demineralization, e.g. using reverse osmosis pressure filters. The water supply for the community of Orogrande, some 5 miles south of the project site, is a surface water supply which is piped from the Sacramento River some 30-50 miles away. This supply system dates from the turn of the century. Some of the pipeline is above ground or shallow buried, and is apparently subject to disruption due to breakage or freezing in winter. It is therefore not likely that this water supply system will be considered to be sufficiently reliable for the project. All surface waters in the general project area have apparently been appropriate.

Air/Noise Resources

■ Air

To date no issues have been identified for this particular resource area.

■ Noise

Weapons firings and supersonic air operations produce peak noises in excess of 146 db. At times these noise sources can be heard in areas off the Range, however, no site specific data is available.

Socioeconomic Resources

■ Employment

To date no issues have been identified for this resource area.

■ Population and Housing

To date no issues have been identified for this resource area.

■ Public Services and Facilities

To date no issues have been identified for this resource area.

- Fiscal Resources

To date no issues have been identified for this resource area.

- Quality of Life

To date no issues have been identified for this resource area.

- Land Use

To date no issues have been identified for this resource area.

Utilities/Energy Resources

- Electric Utilities/Telephone/Pipelines

To date no issues have been identified for this resource area.

- Magnetic Fields

See Appendix B, White Paper on Electromagnetic Fields or 3.2.1, Non-Site Specific Issues, Technology.

- Energy Resources

To date no issues have been identified for this resource area.

- Industrial and Construction Resources

To date no issues have been identified for this resource area.

Transportation

- Road System

To date no issues have been identified for this resource area.

- Railroads

To date no issues have been identified for this resource area.

- Airports

To date no issues have been identified for this resource area.

- Public Transportation

To date no issues have been identified for this resource area.

Hazardous Wastes

To date no issues have been identified for this resource area.

Cultural Resources

The general area appears to have been investigated but the parameters of a 1985 study are vague. It is also possible that the stipulations of the MOA governing White Sands Military Reservation may apply to Orogrande.

The site contains archaeological remains believed to reflect a land use pattern involving seasonal exploitation of basin floor resources. Recent excavations of small basic floor sites suggest that many of the medium to large formative period sites will contain small huts or pithouses. During field investigations, archaeological remains were observed at Orogrande.

Other Issues

An area just west of the site is overflowed by Pershing IA missiles during test firings. Although no direct impact is expected, there would be reduced reaction time for flight safety personnel and potential for premature destruction of a missile should it stray.

OROGRANDE SITE

SIGNIFICANCE MATRIX BY MAJOR RESOURCE AREA

RESOURCE AREA

<u>NEPA Criteria</u>	<u>Biological Resources</u>	<u>Geology Water</u>	<u>Air/Noise</u>	<u>Socioeconomic</u>	<u>Utilities/ Energy</u>	<u>Transportation</u>	<u>Hazardous Waste</u>	<u>Cultural Resources</u>	<u>Other Issues</u>
1. Beneficial or Adverse Impact	PS	PS	NS	NS	NS	NS	NS	PS	NS
2. Affects Public Health or Safety	NS	NS	NS	NS	NS	NS	NS	NS	NS
3. Unique Geographic Characteristics	NS	NS	NS	NS	NS	NS	NS	NS	NS
4. Controversial Impact on Human Environment	NS	NS	NS	NS	NS	NS	NS	NS	NS
5. Uncertain or Unique Risks	PS	NS	NS	NS	NS	NS	NS	NS	NS
6. Establish a Precedence	PS	NS	NS	NS	NS	NS	NS	NS	NS
7. Cumulative Significant Impact	NS	NS	NS	NS	NS	NS	NS	NS	NS
8. Adversely Affect Resources	NS	NS	NS	NS	NS	NS	NS	PS	NS
9. Threatened or Endangered Species	PS	NS	NS	NS	NS	NS	NS	NS	NS
10. Violation of Federal State and Local Laws	PS	PS	NS	NS	NS	NS	NS	PS	NS

LEGEND:

N.S. = No Significant Issues Identified to Date.

P.S. = Potentially Significant.

TU Electric Monahans Site, Texas

Biological Resources

■ Vegetation

To date no issues have been identified for this resource area.

■ Wildlife

Populations of wildlife in the immediate vicinity of the site could expect effects ranging from premature mortality to temporary construction noise displacement.

The site is located under a major avian flyway. However, due to the lack of water in the vicinity, it is unlikely species will inhabit the area long enough to exhibit adverse effects.

■ Aquatic Resources

To date no issues have been identified for this resource area.

■ Wetlands

To date no issues have been identified for this resource area.

■ Threatened and Endangered Species

Seven federally listed threatened and/or endangered species and four candidate species have ranges that may include the general area: The American peregrine falcon, arctic peregrine falcon, bald eagle, interior least tern, piping plover, black-capped vireo, and possibly the whooping crane. Candidate species are: western yellow-billed cuckoo, southern spotted owl, Arizona prairie dog, and one species of cyprus.

The Texas horned lizard is the only state or federally threatened species on site that could be effected by operation of SMES-ETM.

Geology/Water Resources

■ Seismic

The SMES-ETM TU Electric Monahans site lies on the western edge of a major oil and gas field, with several hundred operating wells, which lies on a N-W to S-E alignment passing in the vicinity of Kermit, approximately 25 miles to the north of TU Electric Monahans. The nearest wells to the project site are approximately 2,000 ft North and 2,000 ft East of the SMES-ETM site. Pressure injection of water, as well as joint injection of water and carbon dioxide, are being carried out at the present time in the TU Electric Monahans area by Chevron Oil for secondary oil recovery.

The 1987 Trans-Pecos Superconducting Super Collider (SSC) proposal which includes data for TU Electric Monahans area describes seismic events and states that there is a possible correlation between secondary oil recovery which has been carried out in the Kermit area, and over 1,000 incidences of minor seismic activity (largest event recorded: 4.1 on the Richter Scale) in the Kermit area.

Air/Noise Resources

To date no air/noise resources issues have been identified for these resource areas.

Socioeconomic Resources

- Employment

To date no issues have been identified for this resource area.

- Population and Housing

To date no issues have been identified for this resource area.

- Public Services and Facilities

To date no issues have been identified for this resource area.

- Fiscal Resources

To date no issues have been identified for this resource area.

- Quality of Life

To date no issues have been identified for this resource area.

- Land Use

To date no issues have been identified for this resource area.

Utilities/Energy Resources

- Electric Utilities/Telephone/Pipelines

Switches, circuit breakers and other terminal equipment in the 138 KV tap line and the Permian Basin - wink 138 KV line may not be able to accommodate 1700 amperes for two minutes. Most of the existing equipment can stand fault current for short periods, but possibly not for long periods.

- Magnetic Fields

See Appendix B, White Paper on Electromagnetic Fields or 3.2.1, Non-Site Specific Issues, Technology.

- Energy Resources

To date no issues have been identified for this resource area.

- Industrial and Construction Resources

To date no issues have been identified for this resource area.

Transportation

- Road System

To date no issues have been identified for this resource area.

- Railroads

To date no issues have been identified for this resource area.

- Airports

To date no issues have been identified for this resource area.

- Public Transportation

To date no issues have been identified for this resource area.

Hazardous Wastes

To date no issues have been identified for this resource area.

Cultural Resources

Prior studies indicate that the cultural resource potential is "moderate to high." The site is used for petroleum production and has a high to moderate potential for the discovery of significant archaeological and cultural resources.

Other Issues

To date no issues have been identified for this resource area.

TU ELECTRIC/MONAHAN'S SITE
SIGNIFICANCE MATRIX BY MAJOR RESOURCE AREA

RESOURCE AREA

<u>NEPA Criteria</u>	<u>Biological Resources</u>	<u>Geology Water</u>	<u>Air/Noise</u>	<u>Socioeconomic</u>	<u>Utilities/ Energy</u>	<u>Transportation</u>	<u>Hazardous Waste</u>	<u>Cultural Resources</u>	<u>Other Issues</u>
1. Beneficial or Adverse Impact	PS	NS	NS	NS	NS	NS	NS	PS	NS
2. Affects Public Health or Safety	NS	NS	NS	NS	NS	NS	NS	NS	NS
3. Unique Geographic Characteristics	NS	NS	NS	NS	NS	NS	NS	NS	NS
4. Controversial Impact on Human Environment	NS	NS	NS	NS	NS	NS	NS	NS	NS
5. Uncertain or Unique Risks	PS	NS	NS	NS	NS	NS	NS	NS	NS
6. Establish a Precedence	PS	NS	NS	NS	NS	NS	NS	NS	NS
7. Cumulative Significant Impact	NS	NS	NS	NS	NS	NS	NS	NS	NS
8. Adversely Affect Resources	NS	NS	NS	NS	NS	NS	NS	PS	NS
9. Threatened or Endangered Species	PS	NS	NS	NS	NS	NS	NS	NS	NS
10. Violation of Federal State and Local Laws	PS	NS	NS	NS	NS	NS	NS	PS	NS

LEGEND:

N.S. = No Significant Issues Identified to Date.

P.S. = Potentially Significant.

Appendix B - WHITE PAPER ON ELECTROMAGNETIC EFFECTS

**SUPERCONDUCTING MAGNETIC
ENERGY STORAGE (SMES-ETM)
ELECTROMAGNETIC EFFECTS**

(Working Paper)

13 November 1989

DMSS/Berger

TABLE OF CONTENTS

	<u>Page</u>
Table of Contents.....	i
Preface.....	ii
Introduction.....	B-1
Electromagnetic Effects of the SMES-ETM.....	B-2
The Nature of the Interaction between Electromagnetic Fields and Organisms.....	B-3
Approaches to Scientific Investigation.....	B-6
Literature Review.....	B-8
Steady Magnetic Fields.....	B-13
Time-Varying Magnetic Fields.....	B-16
Summary and Conclusions.....	B-21
Bibliography.....	B-22

LIST OF TABLES

	<u>Page</u>
Table 1 - Tabulation of Studies on the Physiological and Health Effects of Steady Electric Magnetic Fields.....	B-9
Table 2 - LLNL Steady Magnetic Field Exposure Guidelines.....	B-14
Table 3 - Exposure Guidelines for Time-Varying Magnetic Fields.....	B-18

SUPERCONDUCTING MAGNETIC ENERGY STORAGE (SMES-ETM)

ELECTROMAGNETIC EFFECTS

Introduction

Two basic origins of force give rise to the universal gravitational force and to electromagnetic forces. These are gravitational mass and electric charge. In this paper, the electromagnetic forces are addressed.

Electromagnetic forces are divided into two components: the electric force generated by an electrical field and the magnetic force generated by the magnetic field. Alternating electrical currents (AC), driven by AC volts, produce oscillating electrical and magnetic fields which in turn produce electromagnetic waves. All three are present at a SMES-ETM and their relationships and significance can be confusing to the non-scientist. The SMES-ETM system operates on very large direct current (DC) during steady state and is accompanied by very large steady magnetic fields.

The term "electromagnetic" used in popular literature is largely synonymous with the term "time-varying magnetic field" used in this paper, reflecting the term used in the scientific literature which has been reviewed. The popular term "magnetic" is largely synonymous with "steady magnetic fields" as used in this paper.

There has been increasing concern over the health impacts of electromagnetic fields from power transmission lines and radio/radar stations. A number of epidemiological and experimental studies have linked various forms of cancer and other undesirable human health effects with these electromagnetic fields. A pure scientist, reviewing this work, can fairly point to the shortcomings of these studies and conclude that the linkages to health effects are unfounded. A recent series of articles in the New Yorker Magazine has highlighted these concerns (Brodeur, 1989) and accused scientists refuting the findings of these studies as being motivated by greed. A fair summary of these studies is that they indicate a strong ground for concern about some potential effects, but do not establish the linkage. Concerns have also been raised about steady magnetic fields associated with DC power transmission.

It is suspected that birds use the earth's magnetic field to navigate. Whereas the magnetic navigation mechanism of certain ocean fish has been established, little is known about the navigation mechanism of birds. There is, therefore, concern over the possible impact of the steady magnetic fields associated with a SMES-ETM on the migration of birds. Again, not enough is known to be able assess the impacts of a SMES-ETM.

Strong steady magnetic fields affect certain biological functions. The mechanisms by which this occurs are fairly well established and safety guidelines have been prepared by various organizations to protect workers and the public. These will be the basis of safety requirements and access limitations at the SMES-ETM. However, it is more difficult to restrict access by wildlife to areas of high field strengths. This raises a concern on the impacts of the SMES-ETM on wildlife.

The purpose of this paper is to differentiate the various types of electromagnetic and magnetic effects associated with a SMES-ETM and to review the work done on their effects and indicate their significance to the SMES-ETM project.

To achieve an understanding of the electromagnetic effects associated with the SMES-ETM, three introductory sections are provided: the first introducing the reader to some basic concepts of physics and electricity and describing the types of electromagnetic and magnetic fields that the SMES-ETM can produce, the second describing in broad terms the type of interaction between these fields and organisms, and particularly the human body, that are described in literature, and the third is a description of the different approaches to scientific investigation into these effects and their strengths and limitations.

This introduction will be followed by a more detailed review of the literature available and the state of knowledge specifically referenced to the impacts of a SMES-ETM. This review addresses steady and time-varying magnetic fields separately, though there are certain effects for which it is not established which type of field is the cause. In addition, the reader should be conscious that electrical fields are continuously associated with magnetic fields and that time-varying magnetic fields are associated with electromagnetic waves. The precise mechanisms causing many of the effects observed are not understood and thus could be either electrical field, magnetic field, or radiation effects.

A concluding section will sum up the conclusions of this analysis and propose measures and further studies to minimize the risks associated with this project.

Electromagnetic Effects of the SMES-ETM

As described in the introduction, electromagnetic forces are divided into two components: the electric force generated by an electrical field and the magnetic force generated by the magnetic field such that the total force is given by the equation:

$$F = Q(\epsilon + v \cdot B)$$

where:

- F is the total electromagnetic force on a particle with an electrical charge Q
- ϵ is the electrical field strength
- v is the velocity of particle Q relative to the field
- B is the magnetic field

The important thing to note is that whereas the electrical field produces a force on a stationary charged particle, the magnetic field produces a force on only a moving charged particle. However, that force could be produced by either the particle moving through the field or the field moving across the particle.

An electrical current produces a magnetic field. A steady direct current (DC) will produce a steady field. An oscillating, alternating current (AC) will produce both electrical and magnetic oscillating fields. The oscillating

electrical and magnetic fields in combination will produce electromagnetic waves at the frequency of the oscillation. This is a form of radiation similar to light and radio waves. In the case of standard AC at 60 Hz (cycles per second) used in the US, these electromagnetic waves will be at 60 Hz, which is an extremely low frequency (ELF).

Therefore, both electrical and magnetic fields are present at a SMES-ETM. A SMES-ETM is not connected directly to the electrical grid with three-phase power lines operating with AC. The AC is converted to DC before being fed to the superconducting coil which forms the magnet. The AC power lines will produce oscillating electrical and magnetic fields and ELF electromagnetic waves. In theory the superconducting coil should produce only steady fields. However, a DC current produced by converting AC three phase current using a 12-pulse converter leaves a negligible ripple at the top of the DC current. Smoothing inductors and filters will further reduce the remaining ripple as it enters the coil.

Thus three-phase AC converted to DC using a standard 12-pulse converter will produce a steady magnetic field combined with a time-varying magnetic field of negligible magnitude. The precise magnitude of the ripple will be determined and may be adjusted during the operation of the ETM.

The Nature of the Interaction between Electromagnetic Fields and Organisms

In terms of the public's general understanding, electricity is normally associated only with the energy provided by power stations or batteries used to power the myriad of devices on which our modern technological society depends. Its most dangerous visible aspect is the possibility of electrical shocks which can vary from a barely distinguishable tingle from a battery to death-dealing massive shock from a high voltage power line or lightning.

However, the interaction between electrical forces and living organisms is much more complicated and electrical phenomena in some form take a significant part in the functioning of our bodies.

Electricity is a flow of electrons through a conductor. Chemical reactions involve the exchange of electrons and electrical charges between atoms and molecules, and life is totally dependent on chemical reactions. Thus chemical reactions and electrical phenomena can be considered as different manifestations of the same basic laws of physics.

Electrons oscillating at 60 Hz as an alternating current in a power line produce electromagnetic waves at 60 Hz. Electrons oscillating at far higher frequencies produce electromagnetic waves in the form of visible light.

While the general principle of an inter-relationship between electricity and organic processes is easy to conceptualize relatively little is known about the precise mechanisms which involve electricity and could be affected by electromagnetic fields. At one end of the spectrum, it is possible to demonstrate a direct relationship through experiment and observation. At the other there is a suspicion of a relationship about which little is known.

It is known that strong emissions of radio waves, including those produced by a power line at 60 Hz, can cause increases of body temperature. The concern here related to the SMES-ETM is to protect facility operators and fauna, particularly birds, from excessive radiation.

It is known that magnetic fields interact with the flow of electrolytes in an aqueous medium involved in several biological processes. This interaction produces the type of forces $F_m = Q \cdot v \cdot B$ described in the preceding section. Therefore, an ionized fluid in a magnetic field will generate a "magnetohydrodynamic" (MHD) voltage proportional to the vessel size, the speed of the fluid (v) and the field strength (B). Blood is an example of such an ionized fluid. In humans, the fluid speed and vessel diameter are larger in the aorta, the single large artery just above the heart, than any other place in the body, so an aortic MHD voltage is predictable and noticeable on an electrocardiogram (ECG).

One example of electrodynamic interaction with weak magnetic fields is the electromagnetic guidance system of elasmobranch fish which includes sharks, skates and rays. The heads of these fish contain long jelly-filled canals with a high electrical conductivity. As an elasmobranch swims through the lines of flux of the earth's field, small voltage gradient electric fields are induced which the fish can detect at levels as low as $0.5 \mu\text{V/m}$ and use to navigate (Tenforde, 1986). (As will be discussed later, no similar navigation system dependent on the earth's magnetic field has been found and documented in birds which could fly through the magnetic field produced by the SMES-ETM.) Another important physiological process that is potentially sensitive to electrodynamic interactions with static fields is the conduction of nerve impulses. Simple theoretical calculations indicate that the interaction of a magnetic field with ionic currents in an axonal membrane is extremely weak (Tenforde, 1986).

Macromolecules with a high degree of magnetic anisotropy (i.e., mini-magnets) will rotate in a static magnetic field and reach an equilibrium orientation that represents a minimum energy state, that is, they will tend to orient themselves like a needle of a compass. Examples of biological molecular aggregates that orient in fields of 1 tesla (T) or less are retinal rod outer segments of the eye, muscle fibers, photosynthetic systems and purple membranes of Halobacteria. Although the magneto-orientation of biologically important structures such as retinal rods can be demonstrated by optical techniques when these units are suspended in an aqueous medium, the implications of this effect for visual functions in live animals and humans is unclear (Tenforde, 1986).

There are also biological examples of cellular structures with permanent magnetic moments in which significant magnetic orientation effects occur. One example is the magnetotactic bacterium in which approximately 2 percent of the dry mass is iron contained in magnetite crystals (Fe_3O_4). These bacteria require a low oxygen tension to survive, and their net magnetic moments interact with the geomagnetic field to produce a downward-directed motion that carries them into the bottom of sediments of their aqueous environment. This fascinating survival mechanism requires that there be opposite polarities of the magnetic moments of bacteria in the northern and southern hemispheres, and this feature of magnetotactic bacteria has been confirmed experimentally (Tenforde, 1986).

Another example of an intact cell that can be oriented magnetically is the deoxygenated sickled erythrocyte (an abnormal type of blood cell). It has been shown that these cells, in which the deoxygenated hemoglobin is paramagnetic, will align in a static 0.35 T field with the long axis of the sickled cell oriented perpendicular to magnetic flux lines (Tenforde, 1986).

There are several classes of organic chemical reactions that can be influenced by static magnetic fields in the range of 10-100 mT as the result of effects on the electronic spin states of the reaction intermediates. One example of such reactions that involves an important biological process is the photo-induced charge transfer reaction in bacterial photosynthesis. The application of an external magnetic field greater than 10 mT decreases the yield of this process when the acceptor has been chemically reduced. The magnetic field effects studied to date occur only when the photosynthetic system is placed in an abnormal state by chemical reduction (Tenforde, 1986).

Four levels of biological effects from time-varying magnetic fields can be defined on the basis of the electrical currents induced in living tissues in accordance with Faraday's law: (1) fields that induce current densities above 1 A/m^2 in tissue can be expected to produce rapid, irreversible effects such as cardiac fibrillation (fine, rapid fibrillar movements that replace the normal contraction of the ventricular muscle of the heart); (2) fields inducing current densities above 10 mA/m^2 lead to reversible visual effects (magnetophosphenes and changes in visually evoked potentials perceived as flickering illumination within the visual field) during acute exposures; (3) the prolonged application of fields that induce current densities in the range of $10 - 100 \text{ mA/m}^2$ can produce irreversible alterations in the biochemistry and physiology of cells and organized tissues, an example being the effects of bidirectional pulsed fields used to facilitate bone fracture reunion; (4) fields that induce current densities of approximately $1 - 10 \text{ mA/m}^2$, which is the range of internal current densities present in organs such as the brain and heart lead to few readily apparent biological effects irrespective of the exposure duration.

It has been reported in a series of articles recently published in the New Yorker Magazine that a group of scientists at the Brain Research Institute of UCLA led by Dr. W. Ross Adey have undertaken a number of experiments demonstrating that weak electromagnetic fields can influence brain and nerve functions and the chemical reactions associated with them (Brodeur, 1989). Relatively little has been published in scientific literature about this work but this should not detract from its potential validity. The effect of electromagnetic fields on calcium dependent brain functions has been discussed in a number of papers (Bawin and Adey, 1976; Blackman et al, 1985; Bawin et al, 1975 and Adey, 1984). More recently Adey has suggested that ELF fields promote cancer in brain cells (Adey, 1986).

In addition to the physical effects observed in organisms when electromagnetic fields of known strength are applied in experiments a number of studies have indicated a relationship between the presence of electromagnetic fields and certain observed phenomena.

Two papers on the use of magnetic fields for homing by pigeons both based on the work by one investigator (Keeton) give contradictory results (Keeton, 1971 and Moore, 1988).

Of greater concern are a number of epidemiological studies associating exposure to weak electromagnetic fields with cancer and specifically leukemia. The very nature of these studies limits them to demonstrating associations of the existence of vaguely defined environmental conditions with the observed incidence of a specific disease. They cannot identify the mechanism by which an association occurs or precisely the type of electromagnetic effect causing the association. Of particular concern to the SMES-ETM project is a study which indicates a high incidence of leukemia among workers in the aluminum smelting industry where workers are exposed to similar magnetic fields produced by DC currents converted from AC currents (Milham, 1982) and the subsequent indication that Milham has carried out more extensive unpublished investigations which also indicate a high incidence of non-Hodgkin's lymphoma with exposure to magnetic fields in aluminum plants (Brodeur, 1989).

Approaches to Scientific Investigation

There is a wide discrepancy between the effects of electromagnetic fields which can be physically demonstrated in experiments as compared to those which are inferred by associating the incidence of phenomena, such as the incidence of cancer, with the presence of electromagnetic fields in a vaguely defined environment. The difficulty in addressing effects between these extremes is to determine under what conditions the potential effects of electromagnetic fields should be seriously considered and mitigated against. The perspectives of the scientist, the administrator responsible for weighing the benefits and costs of the project, and the potentially affected public who feel threatened by an invisible force beyond their control, as to where this line should be drawn are obviously all different.

In order to arrive at a rational basis for discussing the environmental and health risks associated with a SMES-ETM facility, the basic approaches in investigating the impacts of electromagnetic fields and the basic strengths and limitations of each are outlined.

The most reliable evidence of a scientific phenomenon is where that phenomenon can be demonstrated in a controlled experiment, supported by theoretical calculations, and the experiment can be consistently replicated with the same results within an acceptable tolerance. In areas such as the interactions of electromagnetic fields and organisms, this is seldom possible and normally only with high-intensity fields. Unfortunately, in the case of the biological effects of electromagnetic fields, such evidence is limited to high field strengths which will not be experienced outside the facility. The only concern is the potential impact on fauna inside the facility. Exposure of workers inside the facility to those fields will be controlled through implementing current industry practices.

Other acceptable levels of evidence include the observation of similar phenomena by several different experimenters, whether or not such phenomena can be supported by theory.

A high level of doubt is engendered when different experimenters claim contradictory results. But unless the experimental methods of one can be demonstrated to be incorrect or there is consistent inability to be able to replicate a phenomenon, there remains the possibility that it may exist.

The epidemiologist, however, has to approach his investigations from a totally different viewpoint when the mechanisms and environmental factors triggering a disease such as in cancer are unknown. He tries to statistically correlate the exposure to specific environmental factors to the incidence of a particular disease. He normally suffers two major handicaps: he cannot isolate one particular environmental factor from a host of other factors, and he cannot establish the level of exposure to the particular environmental factor of an individual suffering the specific disease he is investigating. As an example of the first problem, vehicular air pollution is suspected of being a carcinogen, and a study may demonstrate that people living near a high traffic corridor have a higher than average incidence of a particular type of cancer. However, the same individuals may be exposed to high levels of industrial pollution, and it will be difficult to determine with certainty whether the industrial or the vehicular air pollution is the cause of the cancer. If the areas of high industrial pollution and automobile pollution do not precisely overlap, he has statistical tools available to help him differentiate between the two potential causes. If he cannot precisely establish which individuals were subjected to one source of pollution or the other and the extent of their exposure, he has great difficulty in establishing his correlation. Often, like a detective, the epidemiologist stumbles across a correlation that was not expected. This appears to have happened in the case of the investigations into the correlation of exposure to electromagnetic fields and the incidence of cancer. Many investigators are limited in the facilities and the accuracy and extent of data at their disposal in undertaking their research, which may impinge on the validity of their results particularly if they are looking for long-term histories. Ultimately, one is dependent on an interpretation of the consistency of evidence in one direction and the professional integrity of the investigators in accepting their results, much as believing the story of a witness in court. This presents the opportunity of people supporting or opposing their findings to establish or question their integrity as a prosecuting or defending counsel may question that of witnesses in a court of law. In summary, a great deal of subjective judgement is unfortunately necessary in assessing the validity of many epidemiological studies.

In interpreting the results of studies, the scientist should tend to accept only established fact in the spirit of a judge in court. At the other extreme, members of the public, particularly if they feel threatened by a new technology, might tend to accept the inference of a phenomenon in the spirit of safety first.

Unfortunately, the journalist seeking to write a readable story, is tempted to put a human aspect onto what should be unimpassioned analysis of data and ascribe motivation, often less than ethical, to one side of a scientific argument.

The administrator has a duty to weigh the benefits and costs of a project, and must enter environmental and health concerns as one factor, albeit possibly a

critical one, in his determinations. He is often faced with political realities rather than scientific fact.

Literature Review

The literature review in this section is to a great extent dependent on review by others (i.e. secondary rather than primary sources). Most of the secondary sources quoted by other authors have not been specifically reviewed, and the interpretations are those made by others. Where the interpretations are those of another author, his name is made clear either by reference to him or by direct quotation.

The major sources used are a study of the biological effects of magnetic fields of a 5500 MW SMES-ETM sponsored by the U.S.DOE (Tenforde, 1986), a paper on exposure guidelines for magnetic fields (Miller, 1987) and a paper on the known thresholds for health effects of magnetic fields based on live studies (Budinger, 1981). Budinger and Tenforde are both from the Lawrence Berkeley Laboratory and Miller is from the Lawrence Livermore National Laboratory (LLNL) at Livermore, California.

In view of the concern expressed on the health effects of electromagnetic fields in a series of articles recently published in the New Yorker Magazine (Brodeur, 1989), the sources quoted in this magazine have been reviewed to the extent that could be located. Unfortunately, this article ascribes motivation of financial gain to those who indicate that the evidence of health risks of electromagnetic fields is unfounded. The author does not effectively support this accusation, while current evidence could support a position that no long-term detrimental biological effect has been demonstrated. This leads to a presumption of possible bias in his efforts to present evidence of health risks. Despite its bias, the article does describe unpublished works which raise new concerns and need to be taken into account. In any case, these articles are bound to heighten public concern, and the issues they raise must be addressed.

Table 1, which summarizes the results of studies on the interactions between steady magnetic fields and organisms, is very largely dependent on the sources listed above.

The studies reviewed address the impacts of steady and time-varying magnetic fields separately. This analysis would indicate that the separation of interactions observed into these two types of fields is not always clear because of the presence of a ripple effect in many DC currents generating steady magnetic fields as described above and the possibly synergistic interactions between time-varying and steady magnetic fields, including interactions between time-varying fields and the earth's magnetic field. Further, it is not always clear that the observed effects of magnetic fields can be properly attributed to steady or time-varying fields. In a laboratory, these different effects can be controlled and measured. In real life situations is not so easy to differentiate them. The literature reviewed makes the distinction between time-varying and steady magnetic fields but it is often not clear to which category

Table 1

TABULATION OF STUDIES ON THE PHYSIOLOGICAL AND HEALTH EFFECTS OF STEADY MAGNETIC FIELDS

Type of Health Effect	Health Effects Noted			Health Effects Noted		
	Source	Field Strength Tesla	Species	Source	Field Strength Tesla	Species
<u>Steady Magnetic Field</u>						
Physiological and morphological transformation of mammalian cells	1	0.35	Not stated			
Mutation						
Chromosomal and DNA damage						
Enzyme kinetics and quenching of superconductivity	6, 7, 8	2				
Nerve conduction	10	1				
	12	1	Humans			
	13	varying				
	15	0.12	Cats			
	16	0.3	Baboons			
	17	2	Humans			
	18	1	Humans			
	19	0.6	Rats			
Nervous system	22	low	Pigeons			
Electrocardiogram anomalies	24	.06	Rats			
Induced EMF	25	.093/.14	Staphylococcus aureus 812			
Behavior	27	.5-12	ciliate <u>Spirostomum ambiguum</u>			
Orientation	28	1.6	Mice			
Growth of tumors checked	30	1.6	Mice			
Gestation and growth	32	.06-6	Rabbits			
Increase in mortality	33, 34, 35, 36	1				
Effects on blood	37	.35				
Water intake and urination increased	38	.0076 (ave)	Humans			
Orientation of retinal rods in an aqueous medium	39	.22	Rats			
Orientation of sickle cells	40	4*10 ⁻⁸	Sparrows			
Weak correlation with hypertension	41	5*10 ⁻⁵	Guinea pigs			
Aneurysm clip twisted off	42	1*10 ⁻⁶	Pigeons			
Circadian Rhythms and effects on pineal cells	43	6*10 ⁻⁵				
		5.2*10 ⁻⁵	Rats			
		1.23*10 ⁻⁴				
Possible correlation with leukemia	44 (see Humans text)					
General affects	45	.06	<u>Drosophila melanogaster</u>			
	46	.04	Humans			

¹ 1Tesla = 10,000 gauss

1. Malinin G.I., W.D. Gregory, L. Morelli, V.K. Sharma, J.C. Houck; Evidence of Morphological and Physiological Transformation of Mammalian Cells by Strong Magnetic Fields; Science 194:844-846, 1976
2. Thomas A. Morris; The Effects of NMR Exposure on Living Organisms, I A Microbiol Assay Br. J Radiol 54:615-621, 1981
3. Baum J.W., L.A. Schairer and K.L. Lindhal, Tests in the plant Transcantia for mutagenic effects of strong magnetic fields, Proc. of Biomagnetics Effects Workshop, April 6-7, 1978, Lawrence Berkeley Laboratory, Berkeley, California, 1978 pp. 15-17
4. Lawrence Berkeley Laboratory, Electrophoretic and electro-optical studies on the conformation and susceptibility to psoralen crosslinking of magnetically oriented DNA by R.J. Roots, G.H. Kraft, R.S. Farinato and T.S. Tenforde (LBL-13601), Berkeley, California, 1981
5. Wolff S., L.E. Crokks, P.A. Brown, R. Howard and R.B. Painter, Tests for DNA and chromosomal damage induced by nuclear magnetic resonance imaging, Radiology 136:707-710, 1980
6. Akoyunoglou G; Effect of a magnetic field on carboxydismutase. Nature 202:452-454, 1964
7. Fordon J.C., M.E. Poydock Sr., G. Basulto; Effect of magnetic fields on the respiration of malignant, embryonic and adult tissue. Nature 211:433, 1966
8. Levengood W.C.; Cytogenic variations induced with a magnetic probe; Nature 209:1009 1013. 1966
9. Rabinovitch B., J.E. Maling, M. Weissbluth; Enzyme substrate reactions in very high magnetic fields; Biophys. J. 7:187-204, 1967
10. Reno V.R.; Conduction velocity in nerve exposed to high magnetic field on nerve tissues, NASA Report NO. NAMI-1089, 1969
11. Schwartz J.L.; Influence of a constant magnetic field on nervous tissue: I. Nerve conduction velocity studies; IEEE Trans. Biomed Eng. BME-25:456-473, 1978
12. Hong C.Z.; Static magnetic field influence on human nerve and a constant in homogeneous magnetic field; Acta Physiol. Acad. Sci. Hung. 43:89-94, 1973
13. Kolta P.; Strong and permanent interaction between peripheral nerve and a constant inhomogeneous magnetic field; Acta Physiol. Acad. Sci. Hung. 43:89-94, 1973
14. Gaffey C.T., T.S. Tenforde; Electrical properties of conducting frog sciatic nerve exposed to high DC magnetic fields; Bioelectromagnetics 1:208, 1980
15. Rosen A.D., J. Lubowsky; Magnetic field influence on central nervous system functions; Experimental Neurology; 95:679-687, 1987
16. Gaffey C.T., T.S. Tenforde, E.e. Dean; Alterations in the electrocardiograms of baboons exposed to DC magnetic fields; Bioelectromagnetics 1:209, 1980
17. Jehenson P., D. Duboc, T. Lavergne, L. Guize, F. Guérin, M. Degeorges, A. Syrota; Change in human cardiac rhythm induced by a 2-T static magnetic field; Radiology; 166:227-230, 19
18. Salles-Cunha S.X., J.H. Battocletti, A. Sances, Jr.; Steady magnetic fields in non-invasive electromagnetic flowmetry; IEEE proc. 68:149-155, 1980
19. Nakawaga M., Y. Matsuda; A strong static-magnetic field alters operant responding by rats; Bioelectromagnetics; 1987 +
20. Lawrence Berkeley Laboratory, Assessment of the immune responsiveness of mice exposed to a 1.5 Tesla stationary magnetic field, by T.S. Tenford and M. Shifrine (LBL-17389), Berkeley, California: Lawrence Laboratory, 1984

21. Lawrence Berkeley Laboratory, Monitoring of Circadian waveforms in rodents exposed high intensity static fields, by T.S. Tenforde, L. Levy and E. Verlerov (LBL-18384) Berkeley, California: Lawrence Berkeley Laboratory, 1985
22. Keeton W.T.; Magnetic interfere with pigeon homing; Proc. Natl. Acad. Sci.; 68:1:102-106, Jan. 1971
23. Moore B.R.; Magnetic fields and orientation in pigeons: Experiments of the late W.T. Keeton; Proc. Natl. Acad. Sci.; 85:4907-4909, July 1988
24. Lyu, B.N., Permanent magnet fields: Influence on oxygen-substrate interactions and possible mechanisms of several biomagnetic effects, Izv. Akad. Nauk SSSR Ser. Biol. 7(3):229-236, 1981 (English translation)
25. Nemec, M., D. Horakova and P. Svozil, Changes in the growth of staphylogphage 812 induced by a homogenous magnetic field, Folia Fac. Sci. Nat. Univ. Purkyn. Brun. Biol 24:73-86, 1983
26. Prasad, N.D., D.A. Wright and J.D. Forster, Effect of Nuclear Magnetic Resonance (NMR) on early stages of amphibian development, Magn. Reson. Imaging 1:35-38, 1982
27. Ripamonti A., E. Etienne and R.B. Frankel, Effects of homogenous magnetic fields on responses to toxic stimulation in Spirostomum ambiguum, Bioelectromagnetics 2:187-198, 1981
28. Cherkasov G.V., Condition of erythrocytes during long-term exposure to magnetic fields, Kosm. Biol. Aviakosmicheskya Med. 17:72-75, 1983
29. Nahas G.G., Magnetic field effects on rodents, Proc. Biomagnetics Effects Workshop, April 6-7, 1978, Lawrence Berkeley Laboratory, 1978, pp34-35
30. Nakhilnitskaya Z.N., L.D. Klimovskaya, Z.F. Kuzmina, V.M. Mastryukova, N.P. Smirnova, S.D. Strzhizhovsky and G.V. Cherkasov, Possible adaptation to strong magnetic fields, Acta Astronautica 10:159-161, 1983
31. Biggs M.W., Studies of biomagnetic effects in mice, Proc. Biomagnetic Effects Workshop, April 6, 7, 1978, Lawrence Berkeley Laboratory, 1978, p. 36
32. Nakagawa M., Detection of electrophysiological responses in rabbits affected by short-term exposure to static magnetic field, Nippon Eiseigaku Zaasshi 38:899-908, 1984
33. Hong F.T., D. Mauzerall, A. Mauro, Magnetic anisotropy and the orientation of retina rods in a homogenous magnetic field, Proc. Natl. Acad. Sci. USA, 68:1283-1285, 1971
34. Geacintov N.E., F. Van Nostrand, J.F. Becker, J.B. Tinkel, Magnetic field induced orientation of photosynthetic systems, Biochim. Biophys. Acta 267:420-422, 1965
35. Becker J.F., F. Trentacosti, N.E. Geacintov, Photochem. Photobiol., 27:51, 1978
36. Becker J.F., N.E. Geacintov, C.E. Swenberg, Biochem. Biophys. Acta 503:454, 1978
37. Murayama M., Orientation of sickled erythrocytes in magnetic field, Nature, 206:420-422, 1965
38. Marsh, J.L., T.A. Armstrong, A.P. Jacobsen and R.g. Smith, Health effects of occupational exposure to steady magnetic fields, Am. Ind. Hyg. Assoc. J., 43:387-394, 1982
39. New P.F., B.R. Rosen, T.J. Brady, F.S. Buonanno, J.P. Kistler, C.T. Bur, W.s. Hinshaw, J.H. Newhouse, G.M. Pohost and J.M. Taveras, Potential hazards and artifacts ferromagnetic and nonferromagnetic surgical and dental materials and devices used in nuclear magnetic resonance imaging, Radiology, 147:139-148, 1983

40. Bliss V.L. and F.H. Hepner, Circadian rhythm influenced by near zero magnetic field, Nature, 261:411-412, 1976
41. Semm P., T. Schneider and L. Vollrath, Effects of an earth strength magnetic field on electrical activity of pineal cells, Nature, 288:607-608, 1980
42. Semm P., T. Schneider, L. Vollrath and W. Wilschko, Magnetic sensitive pineal cells in pigeons, In Avian Navigation, International Symposium on Avian Navigation (ISAN) held in Tirrenia (Pisa), September 11-14, 1981, Epringer Verlag, Berlin, 1982 pp. 329-337
43. Welker H.A., P. Semm, R.P. Willig, J.C. Commentz, W. Wilschko and L. Vollrath, Effects of an artificial magnetic field on Seritin N-Acetyltransferase activity and metabolism content of rat pineal gland, Exp. Brain Res. 50:426-432, 1983
44. Milham S.J., Mortality from Leukemia in workers exposed to electrical and magnetic fields, Engl. J. Med., 307:249, 1982
45. Koana T., D. Yajima, M. Okada and M. Nakagaw, Abnormality in external morphology of Drosophilla induced by magnetic field, 15th Annual meeting of the Japanese Society of Development Biologists, Tokyo, May 27-29, 1982, Dev. Growth Diff 24:418, 1982
46. Reid A., F.w. Smith and J.M.S. Hutchison, Nuclear magnetic resonance imaging and its safety implications: Followup of 181 patients, Br. J. Radiology, 55:784-786, 1982
47. Kellman B.J., R.L. Rommereim and D.P. Mahlum, Effects of static homogeneous magnetic fields on mice during lifetime exposure, paper presented at Twenty-Third Hanford Life Science Symposium, Richland Washington, October 2-4, 1984

an observed effect belongs. Tenforde refers to the aforementioned study of the incidence of leukemia among aluminum workers under the effect of a static (steady field), while Miller considers it under the category of time-varying fields. In fact, these workers were subject to both types of field as well as ELF radiation, and if there is a mechanism to trigger leukemia it is far from clear which source is responsible.

Steady Magnetic Fields

Budinger, publishing in 1981, states: "There is no positive scientific evidence for detrimental human health effects from static magnetic fields." Tenforde states in 1986: "In regard to mammalian species, there is now substantial evidence that static magnetic fields do not produce adverse behavioral or physiological changes at a level up to approximately 2 T." Miller, publishing in 1987, does not make such a sweeping statement but his work could support the same interpretations. Having reviewed the evidence of the effects of steady magnetic fields he states:

"Other animal test data tend to support a belief that steady magnetic fields are not particularly hazardous. This may also help to explain why early bioeffects research was not highly productive - the effects of steady magnetic fields are subtle, and so, routine control procedures used in biological experiments allow spurious experimental variables to mask the actual bioeffects or the lack of them."

As described above, both theoretical calculations and experimental results indicate that strong magnetic fields do influence certain bodily functions, albeit on a temporary basis while exposure occurs. Therefore existing safety standards have been developed to limit the exposure of people above levels where they could suffer ill effects. For example, a 60 mT exposure guideline was developed at the Lawrence Livermore National Laboratory (LLNL) (see Table 2) to limit the average MHD voltage to 1 millivolt (mv) in an obese person engaged in moderately heavy work. 1 mv is the level tolerated by test primates without evidence of ill effects. An obese person has more blood and larger vessels than a person of average build (Miller, 1987).

Modern medicine has introduced electronic and mechanical devices such as artificial cardiac pacemakers and prosthetic devices into the bodies of some people. These are influenced by magnetic fields and the levels at which their functions suffer are more easily established than subtle biological effects. According to Miller, the operation of several pacemakers have been checked and shown to switch into potentially dangerous modes in magnetic fields as low as 1.4 mT and the reed switches will relax at lower magnetic field strengths, sometimes as low as 0.8 mT (Pavlicek et al., 1983 and Siemens, undated). He indicates that the Food and Drug Administration (FDA) now advises manufacturers of nuclear magnetic resonance (NMR) units to label them to warn pacemaker users to stay out of places where the field exceeds 0.5 mT (FDA, 1984). He states that LLNL has set the warning level at 1 mT (see Table 2) for three reasons: "1) warning at the 0.5 mT level would have meant blocking off a major road on site; 2) no artificial pacemaker has been identified that has a reed switch that

functions below 1.4 mT; 3) the quality assurance testing of reed switches is exceptionally stringent." (Miller, 1987)

TABLE 2
LLNL STEADY MAGNETIC FIELD EXPOSURE GUIDELINES

Field Strength (mT)	Action
1	Exclusionary warning for pacemaker users
1	Cautionary warning for those with prosthetic implants
50	Action limit - Training and medical surveillance required. Persons with sickle-cell anemia prohibited.
60	Time-weighted average (TWA) exposure criterion for the trunk
500	Definition of strong magnetic field. Averaging period for TWA exposure calculations changes from 40-hr workweek to 8-hr workday when exposures exceed this level.
600	TWA exposure for the extremities.
2000	Peak exposure criterion.

Source: Miller, 1987

Prosthetic devices, or implants, have a wide variety of shapes and sizes, use different materials and are fixed to the body by different means. Therefore it is not possible to indicate a field strength at which all devices will be affected. According to Miller it has been demonstrated that an aneurysm clip implanted on the femoral artery of a rat was rotated but not pulled off in a field of 0.105 T and a magnetic field gradient of 0.2 T/m while a similar clip came off in a field of 0.22 T and a field gradient of 2.1 T/m (New et al., 1983). He indicates that at LLNL, people with small prosthetic implants are kept out of areas where the field exceeds 1 mT. Persons with medium-sized implants are treated on a case-by-case basis. Persons with large implants are advised to avoid entering places where fields exceed 1 mT and to report where they begin to feel their implants so that field strengths and gradients can be measured there.

Table 1 addresses some of the studies on the biological effects of steady magnetic fields. Tenforde states: "there is an increasing database which suggests that mammals experience no adverse effects from exposure to fields with flux densities up to the highest levels to which man is generally exposed, i.e. 1 to 2 T.

With respect to the effects of static magnetic fields on the orientation of birds and insects, Tenforde's summary which states, after pointing out that elasmobranch fish will not be in the zone of influence of a land-based SMES-ETM:

"A different situation exists for bees and migratory avian species, which have been claimed to derive directional cues from the geomagnetic field in the absence of direct sunlight. Controversy currently exists in regard to the question of whether an altered magnetic environment can affect the orientation of the waggle dance by bees to communicate the direction of food. The sun provides a primary directional reference in both the navigation of bees and their dance language, and it has been proposed that geomagnetic orientational cues serve as a secondary source of directional information under overcast skies. However, recent careful studies indicate that geomagnetic information is not important since bees apparently possess a memory from previous days of the sun's position at each time of day relative to their flight direction or other landmarks (Dyer & Gould, 1981).

"The evidence that migratory avian species (e.g. pigeons, gulls and robins) respond to directional information from magnetic fields in the absence of sunlight is now reasonably well established. Unfortunately, nearly all of the available information on this subject has been obtained either from field tests in which small magnets were attached to the heads of migrating birds, or from laboratory studies in which birds were placed in cages surrounded by Helmholtz coils to produce an altered magnetic environment. The avians in these studies were thus subjected continuously to magnetic fields that differed from the natural geomagnetic field. It is difficult to assess from these investigations whether the long-range navigational route of a migratory avian species would be significantly influenced if a transient alteration in the ambient magnetic field were to be encountered during nocturnal navigation or during daytime migration under overcast skies. This type of transient magnetic field disturbance would be presented to avians flying over or near an SMES-ETM facility, and it poses an environmental problem that will be difficult to resolve even by implementing the various shielding options discussed in Section 2."

Thus the navigation systems of avians and insects is poorly understood. It is far from clear what effects a SMES-ETM facility would have on migratory birds and the construction of an ETM could provide an opportunity to observe its effects.

The significance of evidence that weak static magnetic fields could promote cancer or other diseases is weak. As previously mentioned, one study correlates the incidence of leukemia with exposure to static magnetic fields in aluminum plants (Milham, 1982). According to Tenforde, magnetic fields to which aluminum industry workers are subject to are found to be as high as 57 mT during the pre-bake period (Tenforde, 1985 and 1986). This is lower than the maximum field strength that SMES-ETM facility workers will be subject to but much higher than that to which members of the public will be exposed. According to Tenforde, the excess of leukemias observed in Milham's study was supported in a subsequent study involving 21,829 workers in 14 aluminum plants (Rockette and Arena, 1983). In this second study, an excess incidence of pancreatic, genitourinary and benign tumors was also found among aluminum workers. However, by their nature, these

studies neither elaborate on the average magnetic field dosage of the sample nor exclude other environmental factors. Pot room workers are exposed to high concentrations of hydrocarbon fumes including the known carcinogen, benzo-a-pyrene. Brodeur indicates that Milham did not find high levels of lung cancer which is associated with the type of pollutants to which workers are exposed but that Milham also found high levels of non-hodgkins lymphoma which are also not associated with the type of pollutants to which aluminum workers are exposed. In summary, a possible but far from established association between long-term exposure to magnetic fields similar to that produced by the SMES-ETM has been indicated.

Miller reports on two studies of industries in which workers are exposed to moderately strong magnetic fields. One report finds a weak correlation between magnetic field exposures and elevated blood pressure (Marsh, et al., 1982). The other found a correlation between magnetic fields and hypotesteremia (Saia, et al., undated). Miller notes: "One confounding factor not considered was the effect of heat (these studies were conducted in hot industries). Heat is a well known stressor of the circulatory system and influences male reproduction."

Time-Varying Magnetic Fields

Magnetic fields in themselves do not produce a force or electric charges or induce an electric current. Only the motion of a charged particle or conductor within the field gives rise to the effect. That effect can be caused either by the particle moving relative to the field, or the field moving relative to the particle. In the case of a steady magnetic field, the charged particle has to move, as for instance blood moves through an artery. In the case of a time-varying magnetic field, the field is continually oscillating relative to the particle producing an oscillating force or an oscillating current in a conductor. Thus the effects of a time-varying magnetic field cannot be totally divorced from those of a steady field, but they are different in terms of quality, oscillating versus uni-directional, and strength being independent of the motion of the affected organism. They also depend on frequency since motion at certain frequencies may be favored and, at others, dampened by the forces.

In practice, many magnetic fields contain both a time-varying element and a steady element. This is true of aluminum reduction, nuclear magnetic resonance imaging and possibly a SMES-ETM.

As previously mentioned, an oscillating magnetic field combined with an ever-present oscillating electrical field produces electromagnetic radiation in the form of extremely low frequency (ELF) radio waves. These impact organisms in a different way.

As will be discussed later, frequency may be a factor in observed effects, which applies only to time-varying fields.

Miller states:

"It can be seen that steady magnetic fields are not highly hazardous. The situation with regard to time-varying fields, however, is not as clear. Recognizing, evaluating and controlling exposures to time-varying magnetic

fields may become important industrial hygiene concerns, particularly in the frequencies generated in the United States by electric current at 60 Hz and by harmonics of it, and by 50-Hz and harmonics of it abroad."

Miller further points out that the World Health Organization (WHO) is proposing to limit time-varying fields so the density of the induced current does not exceed 0.01 A/m^2 (Microwave News, 1987). Tenforde developed a formula for calculating the field strength necessary to induce such a current in the heart and brain. Using this equation, the field necessary to produce such a current density is calculated as 1.7 mT. Another investigator, using a similar approach, developed an exposure guideline of 1.4 mT at 60 Hz (Dennis, 1985). Table 3 shows the exposure guidelines developed in this manner. According to the method of calculation described in an earlier section, the time-varying component of the SMES-ETM field at the facility boundary should be 13.4% of 1 mT or 0.134 mT at 360 Hz which is close to the exposure criteria in Table 3.

Miller continues that the earliest recorded bioeffect of steady or time-varying magnetic fields are magnetophosphenes - the flickers of light that occur when a person is in a time-varying magnetic field of more than 10 mT. He states that it is possible that the field generates a transretinal electric current that polarizes the postreceptor synaptic membrane that in turn alters the post-synaptic transmission of electrical information. Miller proceeds to state that while this effect has historical significance, there is no evidence that it is harmful. Dennis's criteria for limiting exposure below 30 Hz (see Table 3) are based on limiting phosphenes. (A relatively recent paper (Rosen & Lubowsky, 1987) indicates that a strong steady magnetic field of 120 mT affected the visual response of cats by significantly decreasing both the amplitude and variability of a visual evoked response. They attributed this effect to the action of the magnetic field at the synapse rather than on axonal conduction.)

Miller continues by commenting on work by Adey and others at the Brain Research Institute at UCLA. Brodeur also comments extensively on Adey and his colleagues' work. Adey left UCLA in 1977 to become Associate Chief of Staff for Research and Development at the Jerry L. Pettis Memorial Veterans' Hospital in Loma Linda, California. Miller reports that Bawin and Adey found that time-varying electromagnetic fields affect the afflux of calcium ions from chick forebrain tissues in vitro. Investigators found that this phenomenon occurs, fades, and recurs as the frequency of a time-varying field strength is changed in the presence of the earth's steady magnetic field (Blackman, et al., 1976 and Bawin, Kaczmarek and Adey, 1975). This finding strongly suggests resonance. He reports that it has been found that a very high frequency (VHF) field (such as produced by a VHF radio station) modulated at ELF can induce the same afflux of calcium ions as an ELF field alone (Miller gives Dennis, 1985 as the source but Brodeur indicates that this work was also done by Adey's group). Miller then continues to describe how Adey and his colleagues found that the activities of calcium dependent enzymes of cell membranes, adenylate cyclase, and protein kinase are influenced by ELF-modulated radio-frequency energy and that calcium dependent cellular functions, secretion of insulin by Islets cells and the cytotoxicity related to SMES-ETM magnetic fields. Brodeur quotes Adey as saying with respect to work done in the field in the 1960s:

TABLE 3
EXPOSURE GUIDELINES FOR TIME-VARYING MAGNETIC FIELDS

<u>Frequency (Hz)</u>	<u>Exposure Criterion (mT)</u>
5	37.5
10	12.9
20	50.0
50	1.7
60	1.4
100	0.84
500	0.24
1,000	0.17
5,000	0.12
10,000	0.11

Source: Miller, 1987 based on Dennis, 1985

"At that time, brain waves were widely regarded as being 'noise' in the cerebral system, and as having little or no direct physiological role in information processing. It was also believed that the excitation of nerve cells required powerful electric stimulation in order to overcome the tenth-of-a-volt electrical field that is known to be present at all times between the surface and the interior of every cell membrane. There appeared to be good reason for this, because the electric charge between the exterior and interior of very thin cell membranes, which is known as the membrane potential, is enormous. It is, in fact, equal to the charge of a two-hundred-thousand volt power line if the power line, instead of being suspended fifty feet in the air, as is customary, were to be placed an inch above the ground. In such a case, though, the power line would, of course, instantly arc over and burn out. That gives some idea of the astonishing resistance to electrical current that is provided by two layers of fat -together only a millionth of an inch thick - that make up the membrane of a cell. Indeed, the insulating quality of the tiny cell membrane is vastly more efficient than most, and perhaps all, man-made materials. The wonder is that every cell in the body functions from birth to death with this extraordinary electrical barrier at

its surface. A major question to be answered, therefore was how this could be so.

"Elul's (a UCLA scientist) work showed us that the protein strands protruding from cell surfaces might act as Trojan horses to permit extremely weak electrical and chemical signals to pass through the barrier of the membrane potential and reach the cell interior. It paved the way for us to consider the possibility that these strands might be sensitive to electrochemical breezes blowing across the cell membranes - much in the manner of a field of wheat in the wind - and to hypothesize that the rhythmic waves they were generating were not just general noise but intercellular whispering; in other words, the sound of brain cells communicating with each other in a private language. Since all brain waves, whether they are dominant EEG waves or the weak electric ripples emanating from the interiors of cells, travel as oscillations through fluid-filled spaces - or gutters, as I prefer to call them - it was obviously important for us to know more about what was going on in those gutters. It was also necessary for us to learn more about the role of calcium, whose prevalence in the brain tissue had fascinated me since my days as a medical student, and whose ions were known to play important roles in the transmission of nerve impulses in the brain."

Brodeur then indicates that subsequent work, including the work referred to above, indicated the brain responses of test animals could be impaired by subjecting them to weak time-varying magnetic and electrical fields, that this impairment was highly sensitive to the frequency of the field and it was subsequently shown that exposure to weak magnetic fields at specific frequencies increased the release of calcium ions bound to brain-cell membranes and to their protruding protein strands. Brodeur refers to one experiment where the response of monkeys to a stimulus was slowed by a 10 V/m electrical field at 7 Hz and to an increase of calcium in chick brains subject to 147 MHz field modulated at 16 Hz.

Miller, in commenting on this work, postulates a number of causes for the effects noted but concludes that the cause has not been established, a view that would appear to be in accord with Brodeur.

Under the heading of "RF Magnetic Radiation Effects", Budinger states:

"The proposed non-thermal effects of RF fields on human behavior and physiology is a controversial subject at present and no mechanism has been proved for the observed effects of weak fields of 100 Hz on animals and human subjects"

and references Bawin et, al., 1973 and Adey, 1981. Having continued:

"Effects of electromagnetic fields on calcium transport, which are repeatable and supported by experimental data, show a 15 to 20 percent change in the calcium bound to brain cells following a 20-minute exposure at 1 to 75 HZ."

he states:

A recent study by Tenforde (1980) has demonstrated that the observed alteration in calcium ion binding does not occur through a thermal energy transfer mechanism."

Surprisingly, Tenforde does not refer specifically to Adey and his colleagues' work nor does he discuss it. Though he quotes 328 references, including many of his own articles, he references Adey only once (Cain, Luben and Adey, 1984), a reference which does not appear to be pertinent to the work described above.

The summary of this data is that weak time-varying magnetic fields may have detrimental effects on brain functions, that this effect is frequency-dependent but the mechanism through which observed effects occur has not at this time been determined. The precise relation to the fields produced by the SMES-ETM has not been analyzed. Thus, the impacts are not known.

Budinger, Tenforde, Miller and Brodeur all address the epidemiological studies on the effects of time-varying magnetic fields. Budinger, writing in 1980, does not address the studies linking cancer to exposure to magnetic fields which have been published more recently, and his analysis is therefore dated. All three remaining authors point to the controversy surrounding these studies. Perhaps Miller best expresses the middle position as follows:

"Numerous epidemiological studies are appearing that suggest that time-varying magnetic fields in the power frequencies could be carcinogenic in humans: these studies are based on evaluations of the rates of leukemia and brain tumor incidence in electrical workers, aluminum workers, amateur radio operators and coal miners (Milham, 1982; Coleman et al., 1983; McDowall, 1983; Wright, et al., 1982; Pierce, 1985; Milham, 1985; Leukemia..., 1985; Lin et al., 1985, Interdisciplinary Environmental Associates, 1985; Nordstrom et al., 1983). This work has been challenged (Calle and Savitz, 1985). Epidemiologists have also compared cancer incidence in households near various electrical distribution system configurations associated with different currents and have associated μ T-range fields with elevated leukemia and tumor rates (Wertheimer and Leeper, 1979 and 1982; Tomenius et al, 1982) although this work is controversial (Fulton, et al., 1980, Interdisciplinary Environmental Associates, 1986). It is noted here that teratogenic effects were noted in miniature swine and rats that were subjected to prolonged exposures to intense 60-Hz electric fields (Douglas, 1984 and Anderson and Phillips, 1985).

"Adey believes that ELF fields could be cancer promoting (Adey, 1986) ... Adey asserts that cancer promotion, at least, starts at cell membranes.

"The epidemiological studies mentioned above are extremely stimulating, but animal studies are needed to resolve whether time-varying magnetic fields are mutagenic, carcinogenic, or teratogenic as suggested by some of these studies. Results from such animal studies and exhaustive epidemiological studies that are equipped to obtain dose-response information are not available at this time."

In summary, there are data to demonstrate a potential for weak time-varying magnetic fields to cause cancer and other health problems but the data to prove the association and the field strengths involved are not available at this time.

Summary and Conclusions

According to the theoretical calculations described, the SMES-ETM will produce a combination of a steady and a time-varying magnetic field. This does not accord with texts reviewed which indicate that an SMES-ETM produces a steady magnetic field only.

The current state of knowledge indicates that there is no basis for concluding that a steady magnetic field would produce any dangerous or irreversible effects on humans or other organisms at field strengths produced by the SMES-ETM. However, high field strengths do effect organisms and are dangerous to persons with medical implants.

Two studies indicate the possible association of cancer with weak steady magnetic fields (Milham, 1982 and Rockette and Arena, 1983). The association with steady magnetic fields is, however, tenuous, owing to the presence of a time-varying field and other confounding environmental factors.

Most authorities appear to agree that weak magnetic fields may impact the navigation mechanisms of migratory birds. However, the literature reviewed would not indicate that such an impact would be more than transient.

Of far greater concern are the effects of time-varying magnetic fields. There are a significant number of epidemiological studies pointing to the possible association between time-varying magnetic fields and cancer. Though these studies are far from conclusive, there are equally disquieting publication of experiments demonstrating the discovery of mechanisms by which weak time-varying magnetic and electrical fields may disturb the functioning of the brain. However, the SMES-ETM will produce low time-varying magnetic fields and members of the public will not be exposed to time-varying fields of an intensity to which there is any evidence of an affect. Wildlife inhabiting or entering areas of high field intensity is of possible concern.

BIBLIOGRAPHY

- Adey, W.R., Nonlinear, nonequilibrium aspects of electromagnetic field interactions at cell membranes, in Nonequilibrium Electrodynamics, Plenum Press, New York pp 221-241, 1985
- Adey W.R., Tissue interactions with non-ionizing electromagnetic fields, Physiol. Rev. 61:435-514, 1981
- Adey, W.R., Electromagnetic fields, cell membrane amplification and cancer promotion, paper presented at Annual Meeting of the National Council for Radiological Protection, Washington, D.C. April, 1986
- Anderson L.E. and R.D. Phillips, Biological effects of swine exposed to 60-Hz electric fields^R, Electric Power research Institute (EPRI EA-4318), Palo Alto, California, 1985
- Bawin S.M., R.J. Gavalas-Medici and W.R. Adey, Effects of modulated very high frequency fields on specific brain rhythms in cats, Brain Res 58:365-584, 1973
- Bawin S.M. and W.R. Adey, Sensitivity of calcium binding tissue to weak environmental electric fields oscillating at low frequency, Proc. Natl. Acad. Sci. U.S.A., 73:1999-2003, 1976
- Bawin S.M., L.K. Kaczmarek and W.R. Adey: Effects modulated VHF fields on the central nervous system, Ann. N.Y. Acad. Sci. 247:74-81, 1975
- Blackman C.F., S.G. Benane, D.E. House, and W.T. Jones, Effects of ELF (1-120 Hz) and modulated (50 Hz) RF fields on the afflux of calcium ions from brain tissue in vitro, Bioelectromagnetics 6:1-11, 1985
- Brodeur P., Annals of Radiation: the Hazards of Electromagnetic Fields, New Yorker Magazine, June 12, 19 and 26, 1989
- Budinger T.F., Nuclear magnetic resonance (NMR) in vivo studies: Known thresholds for health effects, J. of Computer Aided Tomography, 5(6):800-811, 1981
- Cain C.S., R.A. Luben and W.R. Adey, Pulsed electromagnetic field effects on PTH stimulated cAMP accumulation and bone resorption in mouse calvariae, presented at 23rd Ann. BPA Hanford Life Sci. Symp. Richland., Washington, October 2-4, 1984
- Calle E.E. and D.A. Savitz: Leukemia in occupational groups with presumed exposure to electrical and magnetic fields, N. Eng. J. Med., 313:1476-1477, 1985
- Coleman, M., J. Bell and R. Skeet: Leukemia incidence in electrical workers, Lancet II:982-983, 1983
- Dennis, J.A., Towards the development of exposure limits for low frequency electromagnetic fields, (Conference Publication No. 25) Institution of Electrical Engineers International on Electric and Magnetic fields in Medicine and Biology, IEE Hitchin, Herts, UK pp 93-97, 1985

Douglas J., Electromagnetic fields and human health, Electrical Power Research Institute J., 9:14-21, 1984

Dyer F.C., J.L. Gould, Science, 214:1041, 1981

Food and Drug Administration, Labelling for a NMR Imaging Product, draft of August 24, 1984, Rockville, MD 20857

Fulton J.P., S. Cobb, L. Prebble, L. Leone and E. Forman, Electrical wiring configuration and childhood leukemia in Rhode Island, Am. J. Epidemiol. 111:291-296, 1980

Interdisciplinary Environmental Associates, Inc., United Kingdom - Two community studies report negative results, Transm. Distrib. Health and safety Report, 4(1):1,9, 1986

Interdisciplinary Environmental Associates, Inc., Case-control study links childhood neuroblastoma with fathers in electrical occupations, Transm. Distrib. health and safety report, 3(7):1-2, August 1985

Keeton W.T., Magnets interfere with pigeon homing, Proc. Natl. Acad. Sci. USA, 68:102-106, 1971

Leukemia in Coal Miners Associated with power-Frequency Fields, Transm. Distrib. Health and Safety Report, 3(8):1-2, September, 1985

Lin R.S., P.C. Dischinger, J. Conde and K.P. Farell, Occupational exposure to electromagnetic fields and the occurrence of brain tumors, J. Occ. Med., 27:413-419, 1985

Marsh J.L., T.A. Armstrong, A.P. Jacobson and R.G. Smith, Health effect of occupational exposure to steady magnetic fields, Am. Ind. Hyg. Assoc. J., 43:387-394, 1982

McDowall M.E., Leukemia Mortality in Electrical Workers in England and Wales, Lancet II:246, 1983

Microwave News, Highlights - WHO-IRPA Health Criteria: Static and ELF Magnetic Fields, 7(2):2-3, 1987

Milham S.J., Mortality from leukemia in workers exposed to electrical and magnetic fields, N. Engl. J. Med. 307:249, 1982

Milham S., Silent keys: Leukemia mortality in amateur radio operators, Lancet I:812, 1985

Miller G., Exposure guidelines for magnetic fields, Am. Ind. Hyg. Assoc. J. 48(2):957-968, 1987

Moore B.R., Magnetic fields and the orientation in homing pigeons: Experiments of the late W.T. Keeton, Proc. Natl. Acad. Sci USA, 85:4907-4909, 1988

New P.F., B.R. Rosen, T.J. Brady, F.S. Buonanno, J.P. Kistler, C.T. Burt, W.S. Hinshaw, J.H. Newhouse, G.M. Pohost and J.M. Taveras, Potential hazards and artifacts of ferromagnetic surgical and dental materials and devices used in magnetic resonance imaging, Radiology, 147:139-148, 1983

Nordstrom S., E. Birke and L. Gustavson, Reproductive hazards among workers in high voltage sub-stations, Bioelectromagnetics, 4:91-101

Pavlicek W., M. Geisinger, L. Castle, G.P. Borkowski, T.F. Meaney, B.L. Beam and J.H. Gallagher, The effects of nuclear magnetic resonance on patients with cardiac pacemakers, Radiology, 147:149-153, 1983

Pearce N.E., R.A. Sheppard, J.K. Howard, J. Fraser and B.M. Lilley: Leukemia in electrical workers in New Zealand, Lancet I:811-812, 1985

Rockette H.E. and V.C. Arena, J. Occup. Med., 25:549, 1983

Rosen A.D. and J. Lubowsky, Magnetic Field Influence on Central Nervous System Function, Experimental Neurology 95:679-687, 1987

Saia B., M. Manno, G. Marcer, L. DeBesi, G. Mastrangelo, C. Foresta, G. Ruzza and I. Mastrogiamco, Hypotestosteremia in Static Magnetic Field (SMF) exposed workers, in a private report from Dr. D. Fisher, Lawrence Livermore National Laboratory, P.O.Box 808, Livermore, California

Siemens Medical systems, Inc., Premarket Application P830081, Summary of Safety and Effectiveness Data, Siemens medical Systems, Inc. 186 Wood Ave., S. Iselin, NJ 08830

Tenforde T.S., Assessment of biological effects associated with magnetic fields from a superconducting magnetic energy storage plant: final report, Lawrence Berkeley Laboratory, April 1986

Tenforde T.S., Thermal aspects of electromagnetic field interactions with bound calcium ions at the nerve cell surface, J. Theor. Biol. 83:517-521, 1980

Tenforde T.S., Magnetic field applications in modern technology and medicine, Proc. Symp. Biological Effects of Static and Extremely-Low-Magnetic Fields, Neuherberg, West Germany, May 13-15, 1985

Tomenius L., L. Hellstrom and B. Enander, Electrical constructions and 50-Hz magnetic fields at the dwellings of tumor cases (0-18 years of age) in the County of Stockholm, in proc. of the International Symposium on Occupational Health and safety in Mining and tunnelling, Prague, Czechoslovakia, June 21-25, 1982

Wertheimer N. and E. Leeper, Adult cancer related to electrical wires near the home, Int. J. Epidemiol. 109:273-284, 1982

Wertheimer N. and E. Leeper, Electrical wiring configurations and childhood cancer, Am. J. Epidemiol. 109:273-284, 1979

Wright W., J.M. Peters and T.M. Mack, Leukemia in workers exposed to electrical and magnetic fields, Lancet II:1160-1161, 1982